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Chapter 30

ARMS INDUSTRIES, ARMS TRADE, AND DEVELOPING COUNTRIES*

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Contents

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Abstract

This chapter discusses developing (non-high income) states' participation in the production and trade of parts or whole units of major conventional weapons, their integration into a transnationalized global arms industry, and the underlying industrial prerequisites that make that participation and integration possible. Drawing on the vertical boundaries of the firm literature, the chapter provides a theory that explains some aspects of post-Cold War shifts in the composition and location of arms production. The chapter further discusses characteristics of the small arms and light weapons industry. A highly lethal industry with far-ranging adverse effects on public health, education, and institutions of law and order and therefore on work incentives and investment climate, it is suggested that the horizontal boundaries of the firm literature, especially the product-cycle hypothesis, may explain certain features of the spacial and temporal diffusion of small arms production, technology, and supply. Newly emerging literature on small-arms demand is also discussed. Furthermore, the chapter examines the widening presence of non-high income states in the production of weapons of mass destruction. Vertical contracting and R&D/patent-race literatures are applied to the case of nuclear weapons.

Major conclusions of the chapter include that data sources are poor, that arms production and trade theory is underdeveloped, and that although non-proliferation regimes may have slowed weapons proliferation, they have failed to stop it. We observe industry entry in all weapons categories and in future may expect to see further increases in industry participation by non-high income states, should they choose to do so. This is the natural consequence of the gradual development of non-high incomes states' production capacities. We also observe, however, that states sometimes exit the arms industry or choose not to participate in it, despite their capacity to do so.

Keywords

ammunition, arms industry, arms production, arms trade, arms transfers, developing states, major conventional weapons, small arms and light weapons, non-conventional weapons, offsets, weapons of mass destruction

JEL classification: D20, F14, H56, L64, O33

1. Introduction

The prospect of violent conflict induces people, as individuals and in groups such as states, to acquire arms. Arms acquisition takes place along a spectrum from self-production to trade, but acquisition by theft, especially of small arms, or by illegal transfer, including the clandestine transfer of critical production technology, is not uncommon. Although agricultural implements and hunting gear can and have been used as weapons, the bulk of the production of arms today is a specialized industrial activity carried out for a political purpose, namely the defense or conquest of a physical space or sphere of interest by threat of violence against enemy populations.

States are not self-sufficient in weapons production. Virtually no regular or irregular armed force is equipped with a comprehensive range of arms that is self-produced in its entirety. Instead, the rule is that self-produced weapons are complemented by weapons imported from elsewhere. Even "self-produced" weapons rely in some measure on imported components or services such as specialized materials, metals, blueprints, software, training, maintenance, repair, and other goods and services. Consequently, trade is invariably part of modern arms industries' business.

Complete weapons or weapon systems once were produced in one state and then transferred to another. The phrase "arms trade" made sense in that context and is referred to here as "whole unit" arms trade. Increasingly, however, trade in arms-related components and services dominates trade in complete systems [Sprague (2004), UK Government (2004)]. It is "people, ideas, and technologies, rather than weapons [that] move across national borders" [Markusen (1999, p. 40)]. A firm in one state may produce a weapons platform, to be stocked with weapons acquired from one or more other states. Training, maintenance, and repair, even financing, are yet different parts of the overall system and can be supplied in many ways. Modern arms production and arms trade now resemble counterparts in other globalized industrial activities such as automobiles, an equally fragmented and transnational industry that includes many developing states as part of the overall production system [Bitzinger (1994)]. Markusen (2004) suggests that the commonly employed phrase "military industrial complex" be replaced with "international military industrial complex". By way of example, the American F-16 fighter jet is assembled in the United States, South Korea, Taiwan, and Turkey with high-tech components supplied by Germany, Israel, Japan, and Russia, and price-sensitive, commercial parts coming from Brazil, Poland, Spain, and South Africa [Markusen and DiGiovanna (2003)].

The industry's transnationalization carries dramatic implications for arms production and arms trade data collection efforts. Twenty years ago, a sale originating in any one state would most likely also have been produced in that state. Today, a sale originating in any one state may still be *credited* to that state but *production* is as likely to take place in a variety of locations around the globe, including the recipient state. Arms production statistics, always having been poor, do not systematically track this "outsourcing". Likewise, arms trade statistics are imputed values that do not necessarily correspond to financial flows and economic burdens. Arms production and trade statistics offered by governments and international organizations are sparse in coverage and detail, and although Revision 3 of the International Standard Industrial Classification (ISIC) code contains a category for weapons and ammunition production, reporting compliance by states is spotty. In some respects, less can be said today than in the past about the volume, location, and flow of arms production and arms trade [Dunne and Surry (2006)].[1]

Another difficulty arises in that today many developing states are bifurcated, exhibiting both extremely well developed economic sectors as well as extremely undeveloped ones. Examples include Brazil, China, India, Russia, Malaysia, Mexico, and Turkey, all with potential or actual arms production levels on par with or exceeding that of states such as Australia, Austria, Belgium, Canada, the Netherlands, Sweden, and Switzerland (see Section 2.2). Additionally, states that 20 or 30 years ago were classified by an average per capita income criterion as developing states, such as Greece, Israel, South Korea, Spain, and Taiwan are now classified as developed or high income states. In contrast, states formerly classified as "industrialized" include Albania and desperately poor former Soviet republics such as Kyrgyzstan. The movement across income categories complicates comparisons to be made among states and over time, a difficulty compounded by the emergence of non-conventional and small arms production and trade activities that have yet to command economists' full attention. This chapter treats all non-high income states, as defined by the World Bank's 2004 per capita gross national income rankings, as developing states.[2]

This chapter reviews what is known about non-high income states' arms industries and arms trade. Section 2 discusses these states' participation in the production and trade of major conventional weapons, their integration into the transnationalized arms industry, and the industrial prerequisites that make that participation possible. This section also offers a new theory of arms production that would explain certain shifts in production location and composition observed in the post-Cold War period. Section 3 addresses the small arms and light weapons (SALW) industry. Highly lethal, it produces far-ranging adverse effects on personal safety, public health, physical infrastructure, and institutions of law and order and therefore on work incentives and investment climate. Economists have studied civil wars [e.g., Collier and Sambanis (2005)] but as yet have not particularly studied the SALW industry that has fueled them. Section 4 examines the widening presence of non-high income states in the production of weapons of mass destruction (atomic, biological, and chemical), also as yet little studied by economists. Section 5 concludes.[3] Chapter 29 in this volume discusses arms trade and arms race theory [García-Alonso and Levine (this volume)], and Chapter 33 studies arms industry procurement and policy issues [Hartley (this volume)]. In contrast, the present chapter emphasizes data-related issues with respect to non-high income states, although some theory is also presented. Arms production, acquisition, trade, or use by non-state actors are not addressed.[4]

2. Major conventional weapons

2.1. *Arms transfers*

Regarding arms transfers, three major data sources are available. They are, first, an annual publication entitled "Conventional Arms Transfers to Developing Nations", produced for the United States Congress by its Congressional Research Service [CRS (2005)]; second, the formerly annual but now irregularly issued *World Military Expenditures and Arms Transfers* (WMEAT), published by the Bureau of Verification and Compliance [BVC (2002)], an agency of the United States Department of State; and, third, the annual *SIPRI Yearbook*, issued by the Stockholm International Peace Research Institute [SIPRI (2005)].[5] Of the three, CRS and WMEAT claim to measure financial values of trade in *all* arms and arms-related goods and services. For example, the CRS

[1] In other respects, more can be said. For instance, within the European Union national arms export reports have become the norm, although the quality of the reports is not always to researchers' liking. For updates, see SIPRI's arms transfer web site at www.sipri.org/contents/armstrad/atlinks_gov.html [accessed 28 September 2005]. On arms industry definition, data, and transparency, also see Bauer (2006), Hartley (this volume), and Surry (2006).

[2] The World Bank classifies economies by income. Based on 2004 GNI data, economies with per capita income of US$825 or less are low-income economies. Other categories are lower-middle income economies (US$826–3,255), upper-middle income economies (US$3,255–10,065), and high income economies (above US$10,065). The 55 political entities in the high income category are Andorra, Aruba, Australia, Austria, the Bahamas, Bahrain, Belgium, Bermuda, Brunei, Canada, Cayman Islands, Channel Islands, Cyprus, Denmark, Faeroe Islands, Finland, France, French Polynesia, Germany, Greece, Greenland, Guam, Hong Kong, Iceland, Ireland, Isle of Man, Italy, Japan, South Korea, Kuwait, Liechtenstein, Luxembourg, Macao, Malta, Monaco, the Netherlands, the Netherlands Antilles, New Caledonia, New Zealand, Norway, Portugal, Puerto Rico, Qatar, San Marino, Saudi Arabia, Singapore, Slovenia, Spain, Sweden, Switzerland, the United Arab Emirates, the United Kingdom, the United States, and the Virgin Islands (US). The special political status of Taiwan prevents the World Bank from listing it but it is treated as a high income economy. Traditionally, researchers refer to all other states as "developing" economies.

[3] So-called non-lethal weapons are not studied here. Exploratory research for a draft of this chapter found that their development and deployment appears as yet limited to a handful of high income states [see, e.g., Dando (2002, 2005), Davis (2005), Lewer and Davison (2005)]. It should be noted that non-lethal weapons are not necessarily non-lethal. For instance, a hostage taking event in Moscow on 23 October 2002 ended in the deaths of about 120 of 800 hostages when Russia authorized the use of a non-lethal chemical (fentanyl) that depresses respiration. Instead, all weapons operate along a continuum of lethality [Lewer and Davison (2005, p. 49)].

[4] For this, see, e.g., Collier and Hoeffler (this volume), Enders (this volume), and Sandler and Arce (this volume).

[5] Among economic researchers, WMEAT and SIPRI have been the most popular data sources. Since the former is not regularly produced anymore (the last data point is for 1999) it is not discussed here. Suffice it to say that the WMEAT data, should a new edition be issued, will not be comparable to earlier editions as major database valuation changes were made in 1997. London's International Institute for Strategic Studies, IISS, annually publishes *The Military Balance* [e.g., IISS (2004)]. It does not provide its own arms trade data; instead, it reproduces some CRS numbers.

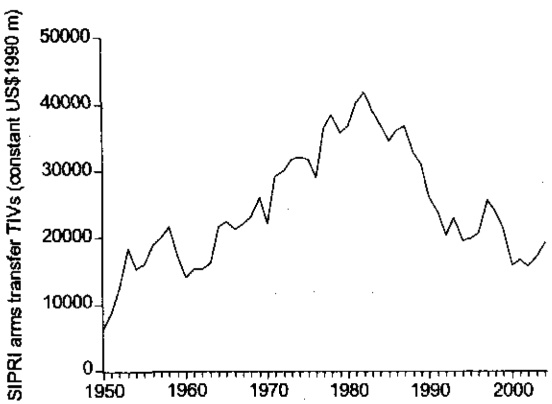

Figure 1. World arms transfer volume, 1950–2004, in constant 1990 US$ million, SIPRI trend-indicator values. *Source*: SIPRI (unpublished data).

defines its scope as pertaining to "all categories of weapons and ammunition, military spare parts, military construction, military assistance and training programs, and all associated services" [CRS (2005, p. 2)]. Transfer data for major conventional weapons are not separated from transfers in other arms. SIPRI is the world's only data source with regard to major conventional weapons alone.

Recognizing that arms transfer volumes, although expressed in US dollars, do not necessarily reflect financial flows, SIPRI refers to its data as "trend-indicator values" (TIVs) and generally refers to arms *transfers* rather than to arms *trade*. SIPRI's arms transfers database tracks deliveries of six categories of major conventional weapons. They are: aircraft, armored vehicles, artillery, radar systems, missiles, and ships [precise definitions are in SIPRI (2005, p. 523)]. Specifically excluded are small arms and light weapons, trucks, artillery under 100 mm caliber, ammunition, support equipment and components, and services and technology transfers. Figure 1 shows world arms transfer volumes, 1950–2004, as measured by TIVs, in constant 1990 US millions of dollars.[6] The high point of the global arms transfer volume as tracked by SIPRI was reached in 1982, at nearly US$42 billion (in constant 1990 US$).[7]

[6] The data for Figure 1 were kindly made available by SIPRI and are published here for the first time. In contrast, the annual SIPRI Yearbook contains data for only 10 years at a time.

[7] Until 1998, SIPRI did not attempt to calculate the annual *financial* value of arms transfers. Calculated from official government data, for calendar year 2003 – the latest estimate available – SIPRI deems that value to lie between US$38–43 billion, or about 0.5 to 0.6 percent of world trade for all goods and services [SIPRI (2005, p. 442)], a relatively modest number. For background information, see www.sipri.org/contents/armstrad/at_gov_ind_data.html [accessed 28 September 2005].

Table 1
World rank and volume of transfers in major conventional weapons, leading suppliers, 1950–2004, selected years (in constant 1990 US$m, SIPRI trend-indicator values)

Country rank/ supplier	Sum 2000–2004	1950	1960	1970	1980	1990	2000	2004	Sum 1950–2004	
01/Russia	26,925	0	0	0	0	0	4,016	6,197	49,169	[1992–2004]
02/USA	25,930	1,446	5,074	7,138	8,588	7,901	6,400	5,453	465,685	
03/France	6,358	15	889	1,608	2,958	1,605	717	2,122	86,230	
04/FR Germany	4,878	0	135	1,096	1,249	1,468	1,195**	1,091**	47,640**	
05/UK	4,450	1,456	1,804	478	1,040	1,569	1,121	985	80,470	
† 06/Ukraine	2,118	0	0	0	0	0	326	452	5,316	[1992–2004]
*** 08/China**	**1,436**	**0**	**282**	**699**	**828**	**848**	**157**	**125**	**35,739**	
‡ 10/Israel	1,258	0	0	13	227	46	272	283	5,598	
† 13/Belarus	744	0	0	0	0	0	261	50	1,837	[1993–2004]
† 14/Uzbekistan	595	0	0	0	0	0	0	170	595	[2002–2004]
‡ 15/Spain	479	0	4	70	11	130	50	75	4,546	
‡ 19/South Korea	313	0	0	0	71	44	6	50	1,328	
† 21/Georgia	248	0	0	0	0	0	54	20	320	[1999–2004]
*** 24/Brazil**	**131**	**0**	**2**	**0**	**158**	**65**	**0**	**100**	**2,578**	
*** 25/Indonesia**	**130**	**0**	**0**	**5**	**4**	**0**	**0**	**50**	**443**	
*** 27/South Africa**	**122**	**0**	**25**	**3**	**24**	**0**	**17**	**35**	**641**	
*** 28/Turkey**	**117**	**0**	**0**	**0**	**11**	**0**	**21**	**18**	**181**	
*** 29/North Korea**	**96**	**0**	**0**	**0**	**5**	**4**	**0**	**0**	**1,996**	
† 30/Kyrgyzstan	92	0	0	0	0	0	0	0	153	[1995–2004]
‡ 33/Singapore	73	0	0	0	0	5	1	70	616	
*** 34/Jordan**	**72**	**0**	**0**	**0**	**0**	**0**	**0**	**72**	**435**	
*** 37/Libya**	**50**	**0**	**0**	**0**	**65**	**36**	**0**	**0**	**919**	
*** 38/Lebanon**	**45**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**48**	
*** 39/India**	**44**	**0**	**0**	**0**	**0**	**2**	**16**	**22**	**190**	
World total	84,479	6,358	14,006	22,069	36,744	26,053	15,838	19,156	1,341,671	

Source: SIPRI (unpublished data).
Note: Numbers preceding states' names are arms export volume ranks (out of 117 states or entities) for the years 2000–2004.
†Formerly part of the USSR.
‡Formerly non-high income states.
***Non-high income states** other than Russia.
**For reunified Germany. Non/high-income state status as per World Bank's 2004 per capita gross national income (GNI) rankings.

In addition to the world's top-5 suppliers for 2000–2004, Table 1 presents arms transfer volume data on the leading arms suppliers among current or former non-high income states (apart from Russia). They include five former republics of the Soviet Union (Belarus, Georgia, Kyrgyzstan, Ukraine, and Uzbekistan), all of whom are non-high income states; four formerly non-high income states that now are high income economies (Israel, Singapore, Spain, and South Korea); and the top-ten non-high income states that are neither former Soviet republics nor states that have progressed to the status of high income economies (highlighted in **bold** type face). Following SIPRI practice, for the listed states the table is rank-ordered by the values for the last five years, 2000–2004.

According to Table 1, apart from Russia, non-high income states as *suppliers* play a minor role in the world arms market. In total, for 2000–2004, the top-10 former and current non-high income states (Ukraine through Indonesia) commanded a modest 8.8 percent of the world market for major conventional weapons. If Israel, Spain, and South Korea are removed from this calculation on the ground that by 2004 all had become high income economies (and if South Africa, Turkey, and North Korea are added to remain at a total of 10 non-high income states), the percentage drops to 6.8. If one further excludes the now independent non-Russian republics of the former Soviet Union to arrive at the 10 states that have been non-high income states for the entire 1950–2004 time-period, then the percentage of arms transfer participation of non-high income states as suppliers drops to a small 2.7 percent of the total for the 2000–2004 period, and about two-thirds of that is accounted for by China alone. This compares to over eighty percent for the world's top-5 arms suppliers. For the 55 year time-period summarized in Table 1, it is clear that supplies to the world arms market by former and current non-high income states are puny, the only exception being Russia. The snapshot listing by decade shows that only China and South Africa have a continuous history of arms exports. The record for the other non-high income states is spotty and small in value. The combined exports of major conventional weapons by Brazil, Indonesia, South Africa, Turkey, North Korea, Jordan, Libya, Lebanon, and India for the entire 55-year time-period are about equal to that of the United States for 2004 alone.

Figure 2 displays arms export volume data from 1950–2004 for 10 selected former and current non-high income states. Drawn to the same scale except for China and Spain, a number of observations may be made. First, Brazil, China, and Israel all appear to have suffered from arms export bubbles. The case of Brazil's short-lived success due to the Iran–Iraq war of the 1980s is well known[8]; those of China and Israel are not. Of the three, only Israel has recovered its arms export volume, in part by managing the post-Cold War conversion process better than most other states [Lewis (2003), Chen (2003)]. Second, most of the depicted states' arms export volumes are subject to severe swings in amplitude, e.g., the Koreas, Singapore, and Spain. Third, the Koreas appear to have entered the export market at about the same time. Fourth, only China, Israel,

[8] Brazil's arms industry has since then collapsed, and so has its arms trade. From 1985–1989, Brazil's TIV was US$1,385m, world-rank #11 [SIPRI (1990, p. 221)]; for 1990–1994, this dropped to US$262m, rank #19 [SIPRI (1995, p. 493)]; and for 1995–1999 to US$99m, rank #30 [SIPRI (2000, p. 372)]. Its US$131m, #24 ranking for 2000–2004 is due to US$100m TIV in 2004 alone. It may, however, be possible to argue that Brazil's successful production of commercial regional passenger aircraft is an outgrowth of its erstwhile military aircraft ambitions [Perlo-Freeman (2004)]. Similarly, from ca. 1975 to ca. 1990, Egypt was a reasonably prominent arms exporting non-high income state, but not since then.

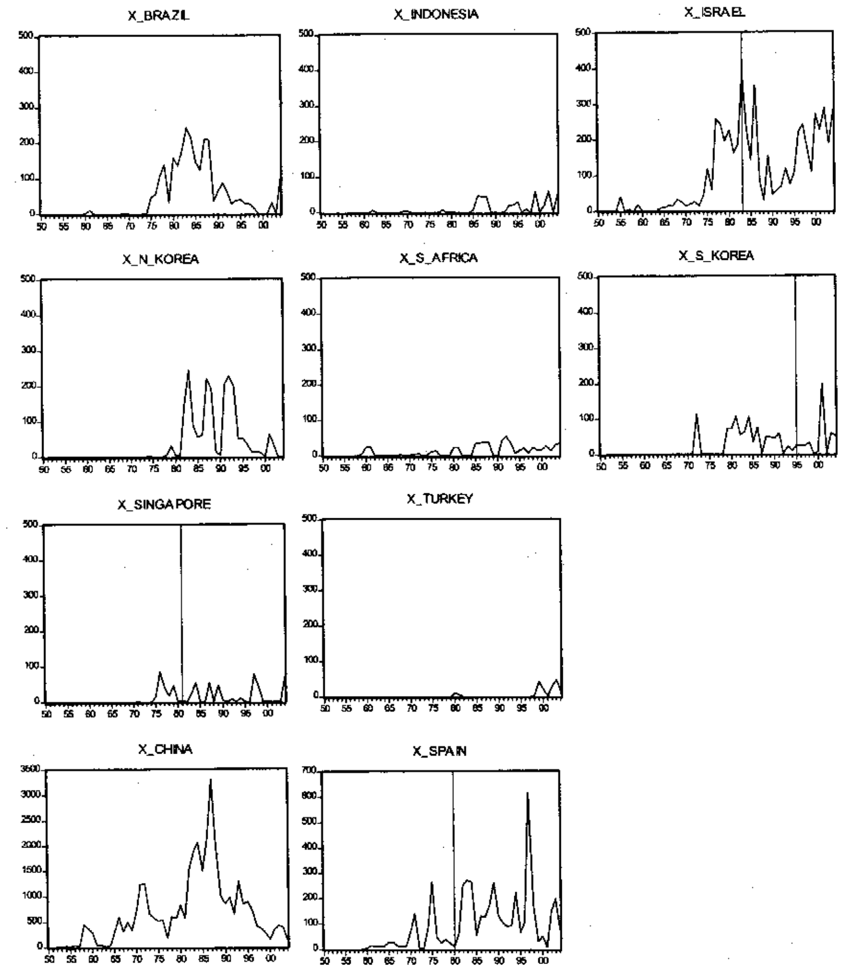

Figure 2. Arms supplies by selected non-high income states, 1950–2004; all figures are drawn to the same scale except for Spain and China; all values are constant 1990 US$ million SIPRI trend-indicator values (TIVs). *Source*: SIPRI (unpublished data). *Note*: The vertical lines for Israel (1983), South Korea (1995), Singapore (1981), and Spain (1980) are set at the years during which they achieved per capita GNP sufficient to count them among industrialized or high income states, as reported in the World Bank's annual *World Development Report*.

South Africa, and Spain have been consistent exporters for most of the time-period. Fifth, Turkey has been a dedicated arms manufacturer since the early 1980s but its lack of arms export performance suggests that its products are not deemed competitive. (Likewise, India – not displayed in Figure 2, but listed in Table 1 – is a minor player in the arms export market.) And sixth, there is no immediately obvious relation between arms transfer volume and transition from non-high income to high income state for the four now-high income states in Figure 2, namely Israel, Singapore, South Korea, and Spain.

Since the main interest in this chapter concerns non-high income economies as arms producers and suppliers, data on arms *recipients* are not presented. Suffice it to say that the top-10 non-high income states received, for 2000–2004, about 41.1 percent of all major conventional weapons shipments,[9] whereas the top-10 high income economies[10] jointly received about 28.6 percent. Six former or current non-high income states – China, India, Israel, Singapore, South Korea, and Turkey – appear as top suppliers and as top recipients. For 2000–2004, all six imported substantially more, in arms transfer volume terms, than they exported. That even the most active former and current non-high income states play but a small part in the international arms market as suppliers of whole unit major conventional weapons stems, in part, from their poverty and small size – so that their overall heft in the market is necessarily minimal – but also from a lack of international competitiveness of their products: Why for example purchase a helicopter made in South Africa when numerous high income states offer more advanced wares at competitive prices?

Even though non-high income states are not particularly successful as arms *sellers*, they nonetheless have undertaken substantial efforts as arms *producers*. These efforts, and the reasons therefore, are discussed in the ensuing section.

2.2. *Arms production*

States produce arms for ostensibly defensive purposes, namely the preservation of territorial integrity and the maintenance of spheres of influence. Underlying this are acute or precautionary political motives [Brauer (2002)]. But the specific form and volume of arms production are more nearly a matter of economics. First, arms export control and supply restrictions impose a constraint that can compel domestic production of arms components or of whole units by otherwise arms-importing states, even if it is economically inefficient to do so. Supply restrictions merely raise the cost of achieving the objective [García-Alonso and Levine (this volume)]. States such as Brazil, China, Egypt, India, Iran, Iraq, Pakistan, South Africa, and Turkey all have been subject to such cost-increasing export-supply restrictions. A competitive market model would reflect a supply restriction as a rise in marginal cost, thus increasing the market price of

[9] They are: China, India, Turkey, Egypt, Pakistan, Iran, Algeria, Yemen, Poland, and Brazil.

[10] Greece, the United Kingdom, South Korea, the United Arab Emirates, Australia, the United States, Israel, Canada, Saudi Arabia, and Italy.

major conventional arms, and hence providing an incentive for market entry either by the restriction-affected state or by other states for whom market entry may now become profitable.

A related, and second, reason for entering domestic arms production is to mitigate or remove uncertainties with regard to the reliability of supply lines so that credible threats of supply interruptions lose their sting. If the recipient were to turn elsewhere, it would be subject to the same threat from a new supplier. In the absence of an effective supply guarantee, the recipient state may thus choose to engage in a minimum of arms self-production. Note that all states mentioned in the preceding paragraph either have or had status ambitions as regional powers (Brazil, China, Egypt, South Africa, Turkey) or were or are engaged in regional conflict (India and Pakistan, Iran and Iraq), i.e., all are cases in which supply restrictions might have proved particularly onerous, thus spurring indigenous arms production efforts. These first two reasons suggest that arms production and trade may be jointly determined [Alexander, Butz and Mihalka (1981)].

Third, it is hoped that domestic arms production might stimulate the domestic economy. Appeal has been made (a) to potential arms export earnings and export-promotion industrialization,[11] (b) to foreign exchange savings from foregone arms imports and import-substitution industrialization, (c) to employment effects stemming from domestic arms production (growth-pole industrialization), and (d) in conjunction with co-production agreements, to military and non-military technology transfers that are to benefit the domestic economy at large (human capital imports embodied in technology). As an empirical matter, these goals do not appear to have been fulfilled [Brauer and Dunne (2004)].

Fourth, arms demand is a function of security preferences, national income, and the price of arms as well as the price of complementary and substitute goods [García-Alonso and Levine (this volume)]. The influence of security preferences on arms demand (imports) has been addressed in the preceding paragraphs. The influence of national income on arms demand is ambiguous. In the absence of domestic arms production data, studies can only measure the effect on the arms import component of overall arms demand. In a recent panel regression study, Smith and Tasiran (2005) found no systematic effect of income on arms imports but did find a non-linear effect of military expenditure (a proxy for security perceptions) on arms imports. As to the third item, prices, Smith and Tasiran (2005) report evidence that arms imports are price sensitive on the order of minus one: a one percent rise in price is associated with a one percent reduction in arms import quantities. Whether a higher arms trade price leads to compensating self-production or co-production (or to displacement into black market trade) or, conversely, whether a price reduction is symmetrically associated with declines in self-production are questions not as yet investigated.[12]

[11] Both President Vaclav Havel of then-Czechoslovakia and President Nelson Mandela of South Africa used this hope as an argument to continue to subsidize domestic arms industries following the overthrow (in 1989 and 1994, respectively) of their predecessor governments [Brauer (2002)].

[12] Also not investigated is the question of the influence on arms import demand of prices of complementary (e.g., weapons training) and substitute (e.g., diplomacy) goods and services.

As is true for the case of transfers in major conventional weapons, SIPRI is also the world's major comprehensive source of information for the production of such weapons.[13] However, data with respect to non-high income states are scarce as data collection efforts are focused on the world's largest arms producing companies.[14] For instance, for 2003 the only non-high income states represented among SIPRI's top-100 arms producing companies are Russia (first appearing at rank 29), India (35), and South Africa (80) [SIPRI (2005, Table 9A.1)]. Data for Chinese companies are unavailable, and they are spotty for Taiwan. Bauer (2006) has proposed six criteria by which to assess arms industry transparency. They are: availability, reliability, comprehensiveness, comparability, disaggregation, and relevance, but an assessment by Surry (2006) finds that even for high income states, usable arms industry data along Bauer's criteria are sparse, in part because reporting obligations that states routinely place on other industries are frequently not placed on arms makers.

Such as they are, the data suggest that, as with arms trade, substantial shifts have occurred with regard to arms production. In the 1950s and 1960s, "First World" and "Second World" states produced whole unit arms and traded a surplus to those who could not produce them (the "Third World"), at least in part to shore up regional spheres of influence. Several fundamental shifts have upset this once straightforward First-to-Third World and Second-to-Third World relation. First, during the 1970s and 1980s, an increasing number of non-high income states made economic progress enabling them to devote some of their improved capacity toward the indigenous production of major conventional weapons. Table 2 shows a quadrupling in the number of non-high income states as exporters of major conventional weapons from the 1950s to the 1980s. (The increasing number of high income states in Table 2 is the result of former non-high income states becoming high income states over time.)

Second, the number of non-high income arms producing states was greater in the 1980s than in the 1950s. But the number of suppliers in the early 2000s is less than that for the 1960s, and that of the 1990s is less than those for the 1970s and 1980s. Although there does not appear to exist any explicit theory on the matter, it is plausible that the "bubble" of non-high income arms producing states from the 1950s through the 1980s was the combined result of improved domestic production capacity and the exigencies of the bi-polar Cold War years that encouraged domestic arms production efforts, even if economically inefficient [Markusen and DiGiovanna (2003, p. 10)]. For example, the Movement of Non-aligned States, founded in the 1950s, included Egypt, India, Indonesia, Pakistan, and then-Yugoslavia and, for a time, China. Brazil, although never a member of the Movement, generally expressed similar policy positions. All entered substantial arms production efforts during the Cold War years.

[13] The *production* of weapons is a flow variable and differs from the *stock* of weapons. According to BICC (2003, p. 158), the stock of major conventional weapons held by "industrialized" states fell from an index of 183 in 1991 to an index of 100 in 2001. In contrast, non-high income states' stock of such weapons remained essentially constant: an index of 105 in 1991 as against an index of 100 in 2001. In absolute numbers, the stock of major conventional weapons in non-high income states of 208,800 pieces is larger than the 199,500 items in possession of industrialized states. A reasonable composite index of weapons *lethality* has not yet been developed. Such an index would need to include not merely the potential lethality of the weapon itself, but also the probability of successful deployment which hinges, among other things, on the training of the attending military personnel.

[14] Thus, while we have some knowledge about states' arms *transfers*, we cannot infer states' arms *retention* as our knowledge of states' arms *production* is incomplete.

Table 2
Count of states as exporters of major conventional weapons, by decade

	1950s	1960s	1970s	1980s	1990s*	2000s* ('00–'04)
High-income	20	25	27	30	32 [32]	26 [26]
Non-high income	9	23	38	37	27 [43]	21 [39]
Total	29	48	65	67	59 [75]	47 [65]
TIVs**	154,688	196,828	315,884	365,873	223,919	84,479

Source: computed from SIPRI (unpublished data).
*Numbers before brackets exclude states formerly part of the Soviet Union, Czechoslovakia, and Yugoslavia, all of which are classified by the World Bank as non-high income states (using 2004 GNI per capita as the criterion). Numbers in brackets include the successor states.
**The TIVs are in constant 1990 US$m.

Third, with the end of the Cold War, the drive for "indigenization" faltered; fixed-cost driven "structural disarmament" [Dunne and Surry (2006)] makes completely indigenous development and production of major conventional weapons unaffordable to all but the United States. Instead, the industry globalized to generate cost savings via specialization in component production, niche market targeting, and supply-chain integration [Dunne and Surry (2006)]. Arms-offset deals proliferate and have become a standard feature of virtually all arms-trade deals, with heavy emphasis placed on co-production, licensing, and – especially – technology transfers [Brauer and Dunne (2004)]. The *raison d'être* motivating indigenous arms production is moving from the politically determined end of the spectrum toward the commercially determined end. Whereas states' defense industrial base used to be defined primarily in terms of home-state based prime and subcontractors [Dunne (1995)], post-Cold War it has become defined in global terms, frequently involving firms that at their core are decidedly civilian producers such as information technology firms [Dunne and Surry (2006)]. Major arms-producing corporations may still be headquartered in the United Kingdom and the United States in particular but various aspects of production are "outsourced", frequently at the demand of buying states (arms trade offsets).

The relative paucity of quantitative state-specific arms production data, as compared to arms transfer data, has led some scholars to take a different tack to learn about non-high income states' arms production. Reasoning that the production of major conventional weapons requires advanced human and physical capital inputs, Kennedy (1974), Wulf (1983), and Brauer (1991, 2000) constructed potential defense capacity (PDC) indices from International Standard Industrial Classification code data and matched these

Table 3
Potential defense capacity (PDC) index for selected high income and non-high income states (1986–1995)*

Group 1**		Group 2**		Group 3**	
Argentina	33.6	Chile	19.4	Australia	33.6
Brazil	51.6	Egypt	24.7	Belgium	34.3
Bulgaria	53.7	Hungary	68.6	Canada	31.5
China	32.5	India	42.1	France	59.7
Czech Republic	37.1	Indonesia	57.2	Greece	44.2
Mexico	61.8	Iran	18.0	South Korea	54.4
Pakistan	13.1	Romania	60.8	Netherlands	26.5
Poland	66.4	Ukraine	55.1	Spain	86.2
Russia	54.1	Yugoslavia	62.9	Sweden	59.0
South Africa	23.0			Switzerland	10.3
Turkey	55.5			USA	64.7

Source: unpublished data based on Brauer (2000).
*The PDC index refers to a percentage that measures in how many of 283 arms-production relevant industrial categories a state recorded production in any year (1986–1995). The categories consist of nine major industry groups: industrial chemicals; other chemicals; iron and steel; non-ferrous metals; metal products; non-electrical machinery; electrical machinery; transportation equipment; scientific, measuring, controlling equipment.
**Group 1 states are non-high income states with continuous, high-level arms production; Group 2 states are non-high income states with continuous, low-level arms production; Group 3 states are high-income arms producing states.

with qualitative, rank-ordered indices of arms production. Covering the mid-1970s to mid-1990s, Brauer (1991, 2000) has shown that the higher is a state's potential to produce arms, the higher is its rank-ordered actual arms production (Spearman rank-correlation coefficient of 0.6). Remarkably, the PDC index for the most arms-production engaged non-high income states exceeded that of the average high income state. Even second-tier arms producers among non-high income states reached an average PDC index lying within 10 percent of that of the high income states. (A selection of states is listed in Table 3.)

A comparison of PDC indices for the group of low-level but continuously engaged arms producers to that of high-level and very engaged arms producers among non-high income states proved statistically equivalent, suggesting that the difference in actual arms production levels, despite comparable potential, is explained by factors such as location: the former group consists of states located in relatively "tranquil" world regions, the latter are in relatively "hostile" world regions. Following the trajectory from the 1970s to the 1990s, the studies further showed that non-high income states engage in domestic arms production as they advance their human and physical capital and reach a PDC level that lies on par with the average high income state. Some non-high income states have arms production potentials they do not fully use (e.g., Mexico, Turkey), others have strained local capacities beyond what they can sustainably deliver (e.g., India, Indonesia), and still others could conceivably produce at a higher level than they have in the past (e.g., Greece, Singapore; both now are high income economies).

2.3. *Transnationalization of arms production and trade*

In the mid-1990s, it was customary to speak of "tiers" of arms production and of an arms production "ladder" that non-high income states could climb as their indigenous capacities improved [Krause (1992), Bitzinger (1994)]. But with the end of the Cold War, non-high income states have been brought into a transnationalized system that includes all products, including arms. Comprehensive data to demonstrate this point are not available. Instead, this view is a judgment based on numerous country, firm, and product-specific case studies [Brauer and Dunne (2002, 2004), Markusen, DiGiovanna and Leary (2003), Dunne and Surry (2006)]. A theoretical explanation is offered in Section 2.4.

Some non-high income states simply abandoned arms production aspirations, for instance Argentina [Cavicchia (2003), Scheetz (2004)], or otherwise significantly retooled their arms production efforts. Conversion from military to civilian products in the 1990s proved much harder for example for non-high income states' platform producers than for subsystem and component producers who more easily adapted to the world arms component market or shifted activity into world commercial markets, or both [see the cases in Markusen, DiGiovanna and Leary (2003)].

Although no guarantee for sustained success, competitively sourced, made-to-order component production, enabled by targeted technology transfer and indigenous technology development, is the key to this diffusion of arms production [Conca (1998), Schwartz (1987), Bitzinger (1994)]. Like the "world car", the "world weapon" [Markusen (1999)] permits non-high income states to enter the industry as parts suppliers at lower entry costs than full-scale, whole unit self-production would require. The 1990s saw spectacular geographic shifts in manufacturing location from high income to former and current non-high income states, resulting in huge investments in technology transfers and skill development. World manufacturing has become modularized and dispersed, and yet systems integrated. Although not to the same degree, the same trend applies to the world armaments market. We now see non-high income states, for example South Africa, exiting certain full-line arms production efforts in favor of entering tailored component production tied to transnational producers headquartered in high income states [Dunne and Lamb (2004)].[15] Consequently, the erstwhile twin monopolies of design and production held by the "West" and "East" (primarily the United States and the former Soviet Union) have eroded. While weapon design remains dominated by high income states, especially the United States – in part because requisite

[15] Other states, such as India, that resist this integration and continue with an indigenous arms production program virtually unchanged from the Cold War years, appear to pay a heavy economic, and potentially military, price for that resistance [Maheshwari (2003), Baskaran (2004)].

R&D expenditures are so burdensome – component, assembly, and fully independent (even if licensed) production is being relocated to former and current non-high income states. This has sparked, certainly in the United States, a debate over arms-offset related production relocation, and Congress now requires of the Administration to provide an annual report detailing, *inter alia*, the economic and employment effects of arms trade offsets on the US economy. For the year 2002, for instance, the United States estimates a loss of 25,450 work-years due to offset agreements it signed that year [BXA (2005, p. 3-2)].

Transnationalization increases the difficulty of putting monetary values to the arms trade. This need not be so as a matter of principle, but appears to hold true for the arms industry [Bauer (2006), Surry (2006)]. A particular trade package may originate in the United Kingdom or the United States and be assigned an arms export value but may be produced in considerable part in the recipient state or another state or states. The average offset *agreement* asked of the United States in 2003 was 121.8 percent of the arms export contract value [BXA (2005, p. v)].[16] Offset *transactions* – in fulfillment of previously incurred obligations – amounted to US$3.6 billion that year, the highest value recorded for the 1993–2003 period. For this time-period, US companies reported 6,593 offset transactions with 46 states for a total value of US$27.1 billion [BXA (2005, p. vi)]. World-wide numbers are not available, but a large number of recent case studies, drawn from every continent, indicate that since the end of the Cold War the industry has seen a spectacular rise in arms trade offset deals through licenses, co-production, and unrelated trade by second-tier high income and non-high income states alike [Brauer and Dunne (2004)]. While the practical details of offset mechanics are inventive, the available evidence suggests that the hoped-for results – cost reduction vis-à-vis arms imports, employment generation via new and sustainable work placement, technology transfer that would spin off to the civilian sector, and consequent generalized economic development – can be documented only in rare cases. Opportunity costs associated with mandated arms trade offsets, to force or compel the development of an indigenous arms industry, appear to be higher than voluntarily negotiated arms trade offsets between supplier company and recipient buyer state [Markowski and Hall (2004)].

Regarding arms production, some small high income states such as Austria and Norway are hardly distinguishable from big non-high income states such as Indonesia or bifurcated states such as South Africa. High income and non-high income states alike are jointly integrated into a *common second tier* dominated by system designers in the first tier [Markusen (1999, 2004), Bitzinger (2003)]. This trend is likely to continue. Yet other tiers are formed by capable non-high income states that do not wish to produce arms (e.g., Mexico) and "stagnating" rather than "developing" states that continue to fall behind in capacity development (e.g., Nigeria). In all, it is questionable whether the

[16] This was due to an unusually high requirement for a single high-valued contract that year. The average offset agreement requirement for the eleven years 1993 to 2003 was 71.4 percent (US$50.7 billion worth of offset agreements out of US$70.9 billion in arms export contracts) [BXA (2005, Table 2-1, p. 2-2)], but with a rising trend.

formerly strict distinction between high income and non-high income arms producing states should still be kept.

It would also appear that the "ladder" model of arms production needs to be abandoned. The point of the "ladder" was to measure how far a state had progressed on the road to arms self-production, even self-sufficiency. During the Cold War period, this served a useful function as states attempted go-it-alone, whole unit production of major conventional arms, but with the end of the Cold War and the transnationalization of the industry a new arms production model would seem to revolve around the diffusion of arms-related technology transfers and foreign direct investment transmitted through various forms of offset work, i.e., issues related to economies of scale, scope, agglomeration and, ultimately, to cost rather than to location. High income and non-high income states alike "pick and choose" just how they wish to participate in the market. Section 2.4 offers a theory that explains some of the observations made thus far.

2.4. *A theory of arms production*

Relatively little work has been done on theoretical models of arms production and trade. A supply-and-demand model by Alexander, Butz and Mihalka (1981) is reviewed in Anderton (1995), as are a Heckscher–Olin based neoclassical trade model, an economies-of-scale model, an economies-of-learning (dynamic increasing returns) model, and models of imperfect competition and arms trade. Anderton (1996) adds a supply-and-demand model with externalities, a small game-theory model, and a product-cycle model. The extensive theoretical work over the past 10 years of a British research group revolving around Paul Dunne, Maria García-Alonso, Paul Levine, and Ron Smith is reviewed by García-Alonso and Levine (this volume). Depending on the research question, each of these theories has its uses. This subsection outlines a new theory. It is based on the "boundaries of the firm" literature [Williamson (1985)][17] and proposes an explanation for the observed shifts in the location and composition of arms production discussed in the prior sections.

Define *vertical integration* in the arms manufacturing sector as an activity that takes place within the confines of a single state, rather than within those of a single firm. A make-decision then is the decision to retain all pertinent weapons production activity within the state (in-state), and a buy-decision is the decision to engage in a cross-border purchase for all or part of a state's weapons needs (out-of-state). A state thus faces a make-or-buy decision-making problem comparable to that a firm within a state faces.

Assuming output to be constant, define, further, *technical efficiency* as the degree to which a state uses least-cost *production* processes – "the steady state production cost difference between producing to one's own requirements and the steady state cost of procuring the same item in the market" [Williamson (1985, p. 92)] – and *agency efficiency* as the degree to which *exchange* processes have been organized to minimize

[17] A textbook version is in Besanko et al. (2004).

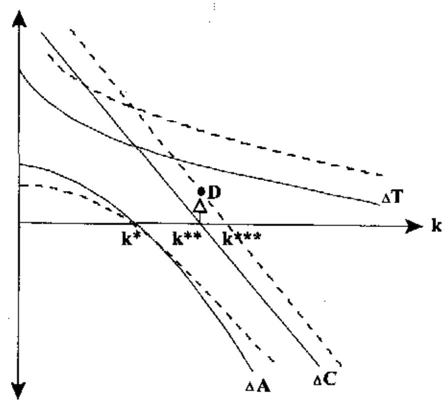

Figure 3. A theory of arms production. *Source*: Based on Besanko et al. (2004, p. 144).

agency, coordination, and transaction costs. For example, when a buy-decision exposes a state to substantial hold-up risk, agency costs of market exchange as opposed to those posed by exchange in a vertically integrated organization (in-state) may not have been minimized. Markets aggregate orders and, on account of the resulting economies of scale, scope, and agglomeration, excel in the direction of minimizing production costs but at the expense of potentially significant agency risks. In contrast, vertical integration excels in the direction of minimizing agency costs [Coase (1937)] but loses the unique advantages competitive markets deliver in terms of production efficiencies. For example, buying critical components from out-of-state because the world market can exploit economies of scale beyond what can be achieved in-state may enhance technical efficiency but perhaps only at considerable contracting costs, including those of contract monitoring and enforcement. Conversely, vertical integration may deliver tighter control over agency-related costs but lose scale efficiencies. Thus, technical and agency efficiency need to be balanced to minimize the sum of both kinds of costs.

Figure 3 [based on Besanko et al. (2004, p. 142)] measures on the vertical axis make-minus-buy cost differences. A positive (negative) value denotes that the make-decision is more (less) expensive than the buy-decision, i.e., vertical integration of a production activity in-state is more (less) costly than using out-of-state exchange. The horizontal axis measures asset specificity, k. Assets can be (a) specific to a location (e.g., an aircraft hangar located near an airfield and flight-training airspace), (b) specific to a particular production purpose (e.g., materials tailored to certain heat-resistance tolerances), (c) specific to physical assets (e.g., a guided-missile production facility), and (d) specific to human resources (e.g., investment in skills training dedicated to military-production related tasks). The more specific the asset, the further out along the horizontal axis it is measured, and the less malleable the asset is for redeployment into alternative uses.

Ignoring all dashed curves for now, in the figure the solid curve marked ΔT is the locus of all make-minus-buy technical efficiency cost minima. Likewise, the curve marked ΔA is the locus of all make-minus-buy agency efficiency cost minima. The first, ΔT, declines as asset specificity k increases. For low values of k, in-state production incurs a cost penalty for "standardized transactions for which market aggregation economies are great" [Williamson (1985, p. 92)]. At low k, it is thus preferable to purchase out-of-state. For example, competitive market firms specializing in the production of heat-resistant materials to high tolerances can spread the necessary R&D over many customers (states), conferring cost advantages relative to vertically integrated in-state production. In contrast, if asset specificity is high (e.g., warhead shockwave-modeling as an input to blast munitions production or nuclear-powered aircraft carriers as an input into the production of national security), then the more specialized uses for the input imply fewer sales outlets for outside suppliers. Consequently, the advantages of scale, scope, and agglomeration dissipate and become less prominent. The cost difference – ΔT – assumes only a small positive value and becomes asymptotic to the asset specificity axis. In other words, the cost disadvantage of in-state production relative to out-of-state acquisition is smaller the larger is asset specificity, k. In the extreme case, an input is unique to the firm (state) and the market's scale economies are exhausted.[18] One important implication is that a firm (state) "will never integrate for production cost reasons alone" [Williamson (1985, p. 94)]. Agency costs drive the integration decision.

Regarding ΔA – agency or governance costs – vertically integrated production is more costly than market exchange (positive values) when asset specificity is low ($k < k^*$) and less costly when asset specificity is high ($k > k^*$). For example, when technology developed in-state is transferred to an out-of-state supplier to produce propellers for military submarines (a highly specific asset), the risk of leakage of critical national security information to third parties rises. In the judgment of decision-makers, this may make ΔA assume a negative value (the agency cost of using the market outweighs the agency cost of in-state production), wherefore vertical integration might be preferred over outsourcing.

The final curve in the figure – ΔC – is the vertical sum of ΔT and ΔA at each k. Thus, to the left of k^{**}, the combined technical and agency costs of in-state production exceed those of out-of-state production ($\Delta C > 0$). Consequently, for low asset specificity, a state should acquire inputs from out-of-state.[19] To the right of k^{**}, the use of highly asset specific inputs argues for in-state production ($\Delta C < 0$). At k^{**} a point of indifference between in-state production and out-of-state acquisition is reached ($\Delta C = 0$). A joint downward (upward) shift of ΔT, ΔA, and ΔC results in a movement of k^{**} to the left (right) and would reduce (enlarge) the range of out-of-state acquisition

[18] Even when scale economies are exhausted, the market may retain scope and agglomeration advantages.

[19] Whether this refers to component inputs into arms production or to arms inputs into national security production does not matter for the theoretical argument.

and correspondingly expand (limit) the range of asset specificity over which in-state production is preferred. In the extreme, k^{**} lies at the origin so that $\Delta C \leqslant 0$ over all feasible k (since k cannot be negative). All arms production would then be contracted in-state.

Consider now a highly adverse international security environment (e.g., the Cold War period) where even allies cannot be fully trusted and agency costs attributable to out-of-state exchange are particularly high, reflecting, for instance, the risk of losing technology secrets through offset production in another, even if notionally friendly, state. Holding ΔT constant, ΔA shifts downward. This would capture a situation in which a state believes that agency costs are so high that no out-of-state producer can be trusted to deliver on a contract. Trusting the market then is *always* perceived to be more costly than in-state production. Consequently, ΔC also shifts downward and moves k^{**} to the left along the k-axis, reducing to zero the range of asset specific inputs acquired out-of-state. All inputs of any specificity necessary for weapons production are now produced in-state.

Technical and agency efficiency may not be independent of each other. For example, since 1982, the demand for, or at least trade in, major conventional weapons worldwide decreased and reduced economies-of-scale benefits. In-state production would be disadvantaged relative to out-of-state purchases, resulting in an upward shift of ΔT for each level of k (the dashed ΔT in the figure). But for low levels of asset specificity, $k < k^*$, the agency efficiency advantages of the market may now be less pronounced as decreased scale may reduce the agency cost of vertical integration while increasing the agency cost of more reliance on the market (additional layers of contracting, for example). In contrast, for high asset specificity, $k > k^*$, the agency advantages of out-of-state relative to in-state production may become more pronounced (for example, hold-up problems within vertical integration may become more serious whereas it may be possible to hedge market hold-up problems against a large number of potential out-of-state suppliers). As a consequence, ΔA *rotates* counter-clockwise around k^* (the dashed ΔA curve in the figure), the slope of ΔC becomes steeper, and k^{**} moves rightward to become k^{***}. Decreased post-1982 demand therefore would have been predicted to increase the range of asset specificity over which out-of-state procurement would occur.[20]

Even if agency effects were symmetric for all k, the combined cost – the dashed ΔC – would shift k^{**} to k^{***} if lower agency costs associated with market exchange relative to the agency costs of vertical integration shifted ΔA uniformly upward. The *threshold* up to which a state should then entrust acquisition of arms production inputs to the market (out-of-state) rises. This may also be seen by comparing k^{**} with point D. For a *given k*, namely k^{**}, the positive value of point D on ΔC represents an excess of make over buy costs. In-state production has become dearer. Insisting, nonetheless, on in-state

[20] For the United States, especially since 11 September 2001, the opposite conclusion would be drawn as demand for military-related goods and services has increased.

production only emphasizes the inefficiency of domestic arms production efforts that some non-high income states appear to insist on even in the post-Cold War world. This, then, would provide an explanation for certain observations made in Sections 2.2 and 2.3, namely (a) that the number and location of arms production by non-high income states has changed in the post-Cold War world (fewer whole unit suppliers) and (b) that the product palette of the remaining non-high income state producers is changing toward supply-chain integration rather than vertically-integrated, in-state, domestic production of whole unit major conventional weapons.

While this model may not be empirically testable (e.g., because of the difficulty of operationalizing a concept such as "asset specificity"), its heuristic usefulness lies in capturing many factors relevant to a state's make-or-buy arms procurement decision. For the defense industry as a whole, and arms production specifically, agency efficiency, technical efficiency, and asset specificity drive the decision-making behavior.

3. Small arms and light weapons

Conventional arms present an enormous potential for concentrated destruction. Yet states use such arms infrequently. In contrast, small arms and light weapons (SALW) are used frequently, by state and non-state actors alike. Today, they are the primary arms to cause injury and death among civilians and military personnel [Bourne (2005, p. 156)]. The *Small Arms Survey*, an annual report of the eponymous project of the Graduate Institute of International Studies in Geneva, Switzerland, estimated that "at least 500,000 people are killed each year by small arms and light weapons" and calls these weapons "the real weapons of mass destruction" [SAS (2001, p. 1)]. As compared to the last major war fought with major conventional weapons – the United States–Iraq war of 2003 – this death toll would be equivalent to a series of major wars being fought each year.[21]

As compared to major conventional weapons, SALW – like land mines – are relatively easy to manufacture (even in home production/craft industry), and because of their low weight they are easily transported, smuggled, and concealed. It has been suggested that the improvement in small arms technology (lighter, hardier, deadlier, simpler, cheaper) is one factor explaining the rise in the number of child soldiers recruited and deployed [Singer (2005, p. 38)].[22] The abuse of SALW causes severe short

[21] The Small Arms Survey 2005 [SAS (2005)] devotes a chapter to estimating conflict deaths (rather than overall SALW-related deaths). Using pre/post-conflict crude mortality rates (CMRs) to calculate "excess" deaths, and using estimates of deaths directly related to violent armed conflict, it finds that for sub-Saharan Africa in the early 2000s, roughly 25 percent of all conflict deaths are "direct" deaths and 75 percent "indirect" deaths (due to conflict-related privation). Of all "direct" conflict deaths, in turn, between 60–90 percent are attributable to SALW. The total (direct and indirect) conflict death toll may be larger than 300,000 people annually.

[22] This combines with an increased "labor pool" of potential child soldiers, generated by factors such as continuous war and the AIDS epidemic that has left millions of orphaned children.

and long-term economic consequences in non-high income states, principally through microeconomic effects on health, education, work incentives, and investment climate that cumulate into adverse macroeconomic outcomes [Collier et al. (2003)]. Magnified through institutional uncertainty or failure (e.g., regarding law and order, and the administration of justice), the result is lagging tax-revenue collection and insufficient economic development [SAS (2003, 2004), Florquin (2005)]. Private and public humanitarian and development aid is made more difficult or altogether impossible by the presence of small arms, with many reported instances of private charities and public agencies withdrawing from field work on account of tangible threats to their workers and the communities within which they work [Godnick, Laurance and Stohl (2005), SAS (2005, p. 251)]. Among the costs of small arms one must therefore count avoidance, prevention, or defensive behavior by those charities and agencies that remain in the field as well as the foregone benefits of work made impossible. Likewise, private corporations operating in non-high income states have seen security expenditures rise, and a burgeoning industry of "private military companies" has sprung up to provide security services [Leander (2005)]. Laurance (2005) provides an overview of the newly emerging small arms research field.

3.1. Definition, data, and market characteristics

Small arms are "revolvers and self-loading pistols, rifles and carbines, assault rifles, sub-machine guns, and light machine guns." Light weapons are "heavy machine guns, hand-held under-barrel and mounted grenade launchers, portable anti-tank and anti-aircraft guns, recoilless rifles, portable launchers of anti-tank and anti-aircraft missile systems, and mortars of less than 100 mm calibre" [SAS (2001, p. 8)]. SALW are long-lasting capital items, wherefore stockpiles are large in relation to the annual flows of weapons production and withdrawal. Correspondingly, the market for ammunition – the most obvious firearms complement – is large as well. (Stockpiles and ammunition are discussed in Section 3.2.)

The Small Arms Survey is the world's foremost data collector and analyst on SALW, fulfilling for small arms the role that SIPRI fulfills for major conventional weapons. The *Survey* provides annually updated information on small arms and light weapons products, producers, stockpiles, trade, and related issues. Since the *Survey* began publishing only in 2001, time-series data that could be used for purposes of inferential statistics are not yet available.

The SALW industry is the most widely distributed segment of the arms industry. Producers of small arms, light weapons, or associated ammunition comprise at least 1,249 companies in more than 90 states [SAS (2004)], including many non-high income states. At least 25 states host illicit (as opposed to legal or legally licensed) small arms manufacturing sites, including such unlikely states as Trinidad and Tobago. Craft or homemade small arms production is not uncommon, for example in Afghanistan and Pakistan. In South Africa, between 1994 and 1999, of 106,000 illegally owned weapons seized by government authorities, 16 percent were homemade.

During the Cold War, the SALW market was duopolistic, dominated by the United States and the Soviet Union. Since then the market has fragmented [Duffield (2001, p. 172)]. Major producers now are high income states such as Austria, Belgium, France, Germany, the United Kingdom, Israel, Italy, Switzerland, and the United States, and non-high income states such as Russia and probably China. The precise reasons for the industry's fragmentation remain uninvestigated, but reasonable hypotheses would include, on the demand-side, the explosion of civil wars, usually fought with SALW, and, on the supply-side, the pursuit of new markets for high income states' weapons products. From the 1980s to the 1990s the number of states and the number of companies producing SALW has been growing. Formerly stable supplier-recipient relations in the legal SALW market have become unstable as selling and acquisition have shifted from political to economic motives [Mussington (1994, p. 163)]. Even the covert small arms market has shifted from global suppliers to regional suppliers (e.g., from Uganda to Rwanda; from Uzbekistan to Tajikistan). One economic reason for this is that the conduct of covert trade carries political risks (e.g., the Iran-Contra arms trade scandal in the United States in the 1980s). That risk is mitigated when arms flow through other countries, and neighbors to states in conflict are best placed to facilitate such flows. Another reason pertains to the complex of issues related to regime security, the provision of security services, and violence-based natural resource extraction and wealth creation, all of which are highly localized affairs that correspondingly encourage the "localization" of the SALW trade [Duffield (2001), Cooper (2006)].

3.2. Trade values, production volumes, stockpiles, and prices

Market value estimates are difficult to establish as even the legal part of the market lacks transparency. Some data for the legal SALW trade (including ammunition) can be obtained from national export reports and from the United Nation's COMTRADE database which, however, relies on voluntary national customs reports and suffers from known defects that result in an understatement of the size of the legal trade. North American and west European states tend to report with some regularity but other major SALW exporters and importers do not. For 2001, the value of documented legal SALW exports amounted to US$2.4 billion [SAS (2004, p. 100)].[23] This is based on the UN's Harmonized System (HS) of reporting. Another estimate for 2001, based on the UN's SITC (Standard Industrial Trade Classification) code, arrives at a US$2.8 billion estimate [SAS (2004, p. 107)], the difference being accounted for by slightly varying definitions used in the HS and SITC codes. Both definitions are more restrictive than the SALW definition offered at the beginning of Section 3.1. When one includes additional SITC codes to capture additional customs transactions related to small arms, the average annual value of the legal SALW trade is thought to lie between US$5–7 billion for 1994–2001 (in constant 2001 US$), similar to the annual world trade in sports

[23] The Small Arms Survey numbers are based on the Norwegian Initiative on Small Arms Transfers (see www.nisat.org).

footwear or frozen fish [SAS (2004, p. 107)]. While this would capture certain military and non-military weaponry in addition to SALW, and would therefore overstate the legal SALW trade, it is also strongly suspected that states hide substantial weapon transfers in innocuous-sounding SITC codes. For example, the SITC "C2" group records customs transactions for swords, cutlasses, bayonets, lances, and parts thereof, in addition to air-guns, rifles, pistols, and truncheons. But it is not credible that between 1994 and 2001, the Netherlands, Germany, the United Kingdom, and others would have traded hundreds of millions of dollars worth of swords and bayonets, as the SITC transaction records suggest. In addition to the annual legal US$5–7 billion SALW trade, the covert, grey, and black markets are thought to constitute an additional 10–20 percent, say, US$1 billion [SAS (2001, pp. 165–168)]. Of the entire trade, the annual global ammunition market is thought to be worth more than the annual global market of the weaponry itself [SAS (2001, p. 15)].

SALW production volume estimates suggest at least 120 million units produced from 1980–1998 [SAS (2001, p. 13)]. The number of SALW products is multiplying and new weapon designs are introduced in part to facilitate the modernization of armed forces in the post-Cold War world. The shrinking size of post-Cold War armies, moreover, has led to surplus weapons being sold (to recover revenue in an era of shrinking defense budgets) and thus being recycled into a burgeoning secondary market [SAS (2004, p. 57)]. Prices of the AK47 assault rifle have been recorded as low as US$15 [Duffield (2001, p. 172)].[24] However, unlike other commodity prices, weapon prices are not systematically collected, foreclosing certain research avenues. A welcome exception is Killicoat's data collection effort [Killicoat (2006))] which reports that AK47 prices in civil-war afflicted states have been constant in current terms (or falling in real terms) between 1990 and 2005, while prices in non-civil war states have increased in current terms. (See Table 4 for a listing of black market prices in selected states.)

The SALW global stockpile has grown to about 640 million units for small arms alone (i.e., not counting light weapons), even as the market for annual production has fallen in size and value [Khakee and Wulf (2005)]. Intentional weapon collection and destruction programs, such as those conducted in association with combatant disarmament, demobilization, and reintegration (DDR), snare relatively few weapons.[25] On occasion, DDR processes have been mismanaged and collected weapons recycled onto the market [SAS (2005, p. 284)]. Stockpile security is exceptionally low. Catastrophic state collapse, such as in Somalia 1991–2 and Iraq 2003, have resulted in the looting of millions of military, police, border, intelligence, and other service weapons. In Albania, in 1997, some 750,000 weapons were thus looted, about 80 percent of the national stockpile [Duffield (2001, p. 171)], an important precursor to the arming of ethnic Albanians in neighboring Kosovo and the ensuing war there that ended with a 78-day US-led NATO air war campaign in early 1999. Even in stable but otherwise poor states, hundreds of thousands of

[24] At one point in 2003, an Arab source reports that in Basra, in southern Iraq, AK47's briefly "traded" for a price of zero [SAS (2004, p. 48)].

[25] From the mid-1990s to the mid-2000s, only about 8 million out of 640 million [see SAS (2004, p. 58)].

Table 4
Black market prices for AK47 assault rifle, selected states, current US$ (1990–2005)*

State/year	1990	1995	2000	2005	State/year	1990	1995	2000	2005
Afghanistan	80	100	100	150	Liberia	100	100	100	45
Algeria	400	400	300	200	Mozambique	160	60	15	30
Argentina	800	700	1,000	1, 200	Pakistan	120	200	200	280
Belarus	150	250	140	160	Philippines	250	300	300	328
Botswana	200	250	200	200	Sierra Leone	270	150	120	100
Colombia	609	800	350	400	Singapore	1,200	1,200	1,500	1,500
Congo, DR	200	215	120	50	Somalia	165	200	120	160
Cote d'Ivoire	180	100	100	120	South Africa	160	200	195	180
Croatia	330	180	250	300	Sudan	150	150	100	86
Iraq	300	250	250	150	United States	420	450	480	500
Israel	2,500	3,000	2,800	3,000	Zimbabwe	200	250	200	150
Kenya	500	100	200	150					
All states**	448	425	559	534					
– civil war	382	376	378	348					
– no civil war	530	464	669	655					
– all African states	235	177	139	140					

Source: Killicoat (2006).
*The data were kindly provided by Mr. Killicoat.
**Sample size varies by year.

weapons are lost annually through graft and theft by officials and uniformed personnel alike [SAS (2004, p. 56)]. Further numbers are stolen from civilian homes and recycled onto the black market. Governments are only slowly instituting reform measures to track ownership, possession, and trade.

Ammunition production, like weapons production, is widely dispersed across the globe. At least 76 states produce small-caliber munitions [SAS (2005, p. 13)]. The companies that produce ammunition are generally not those that produce the weapons [SAS (2005, p. 13)]. The two industries are separate from each other (as is the small arms industry from the light weapons industry). Small arms ammunition consists of primer, propellent, projectile, and a casing, each of which in turn tends to be produced in distinct industries; ammunition factories are often no more than assemblers of the final product [SAS (2005, chapter 1)]. Technologically, ammunition production is generally simpler than the production of the corresponding weapon, requiring little more than simple explosives and basic metal fabrication skills, even if to some tolerances. Production machinery is widely available on the world manufacturing market. This suggests low industry-entry costs and considerable scope for competitive pricing. Nonetheless, the number of primer producers worldwide is small, apparently in part because primer production involves more complex skills and tools than other ammunition components [SAS (2005, pp. 13, 30)]. There is some evidence that, as for the case of major conventional weapons, the more industrially capable a state, the more likely that it will be engaged in ammunition production.

3.3. *Supply, technology, diffusion*

In spite of falling annual production runs, SALW production is dispersing across more suppliers and more states. The requisite technology is often simple (more so for small arms than for light weapons), and production costs can be quite low. The AK47 assault rifle for instance, designed in 1947, received a much disregarded patent only in 1999; its design simplicity – it has only nine moving parts – has spawned widespread design copying, and it can be manufactured for well below US$100/unit [SAS (2001, p. 17)]. Few specifics are known about the underlying production technology and its diffusion over time and geography. Licensing of SALW appears commonplace, perhaps more so than for major conventional weapons, and in a number of cases has led to the complete transfer of production lines overseas. By way of example, production of man-portable air defense systems (MANPADS) – a relatively sophisticated product – has migrated in the form of derivatives, copies, or licensed production from China to Pakistan and North Korea, from Russia to China, Egypt, Romania, Bulgaria, North Korea, Poland, and Vietnam, and from Sweden to Pakistan [SAS (2004, Table 3.2, p. 82)]. Among assault rifles, the Kalashnikov AK series has been licensed to at least 19 states, Hechler & Koch's G3 to at least 18 states, and Herstal's FN-FAL to at least 15 states [SAS (2001, Table 1.4, p. 20) where additional examples may be found]. Unlike for the case of major conventional arms, a large number of non-high income states have become successful exporters of SALW produced under license [SAS (2002, pp. 40–54)].

SALW production and diffusion do not appear to have been specifically theorized in the economics literature. An initial hypothesis might simply pose that firms in high income states run against "horizontal boundaries". Economies of scale and scope having been exploited at home, the profit-maximizing move might be to transfer mature product lines overseas.[26] The original manufacturer gains license fees, increasing the return on the initial R&D, while freeing up limited design and production capacity for new product lines and redeploying skilled personnel to higher-valued pursuits. Vernon (1966) emphasized that mature product lines also migrate out-of-state to better capture information available in local markets and thus to adapt the product to local needs: ". . . producers in any market are more likely to be aware of the possibility of introducing new products in that market than producers located elsewhere would be" [Vernon (1966, p. 192)]. Licensing can also be used to circumvent home-state export restrictions and to compete for market share overseas. For the licensee, advantages include domestic production using proven design and technology, thus curtailing the economic risk of self-production or the economic cost of imports.

The product life-cycle hypothesis hints at why the thought that small arms technology has reached a technological plateau and is "likely to remain on this plateau for years to come" [SAS (2004, p. 20)] is perhaps wrong. The basic firearm platform may not have changed much in 50 years, but innovations and add-ons have drastically increased the portability, durability, range, accuracy, and penetrating power of firearms

[26] This is Vernon's (1966) product life-cycle hypothesis.

[see also SAS (2003, pp. 20–25)]. The trajectory may instead be one of incremental advance within a mature technology, similar to the way that innovations in complementary electronics have enhanced performance for example of unmanned aerial vehicles. Significant advances in materials science, precision production processes, and weapons and ammunition design include innovations such as sound and flash suppression technology, night scopes, armor-piercing ammunition, and fragmenting munitions. Moreover, add-ons such as range finders, laser targeting, and rapid fire mechanisms enhance the weapon as well. For armed forces, all such innovations are associated with the search for increased battlefield flexibility and higher kill-per-shot "productivity", but for R&D-intensive *producers* they represent the employment of scarce resources better not spent on maintaining mature product lines. It is thus likely that these innovations, once they in turn mature, will find their way from producers in high income states to those located in non-high income states. In addition to the assault rifle and MANPAD cases mentioned earlier, another example is that of the RPG-7, a more than 40-year old rocket-propelled grenade launcher design, variants and derivatives of and ammunition for which now are produced by at least 11 non-high income states. The low cost of the weapon (used: US$10), its rugged design, light weight, and easy upgradability for a variety of cheap munitions make it a preferred weapon for state and non-state actors alike.[27]

Ammunition is a complement to SALW. It is frequently the ammunition, not the weapon, that is the limiting factor to SALW use, misuse, and abuse [SAS (2005)]. For instance, during the 1994 Rwandan genocide, victims often were rounded up with firearms but slaughtered with bladed weapons to conserve ammunition (i.e., the lack of the firearms complement induced weapons substitution). Groups elsewhere, for example in Mali, have been documented to source or craft-produce weapons to fit munitions stolen from police or military depots. Ammunition has limited shelf-life as propellents degrade, especially when improperly stored in the more extreme environmental conditions found in many non-high income states. Also, the cost of ammunition – a consumable – can quickly outweigh the cost of the weapon, so much so that cash-strapped groups have been documented to severely punish group members for injudicious ammunition use [SAS (2005, pp. 18–20)]. Not much is known about SALW training, maintenance, and repair (TMR) requirements, another complement to SALW. One would predict that the higher the TMR cost, the less pervasive the spread and penetration of SALW throughout the world. Anecdotal evidence would support this view. A case study on MANPADS for instance suggests that training requirements for proper operation are extensive [SAS (2004, p. 85)].

Supplier, intermediary, and recipient states – or actors in those states – each need to deal with different, if any, small-arms related laws and regulations. It is not straightforward to determine whether any particular SALW trade is a legal, covert, grey, or black market activity. An arms transfer from a state to a broker may be legal under the transferring state's laws, but the broker's follow-on trade through intermediaries may not be

[27] Non-high income state RPG-7 producers: Bulgaria, China, Egypt, Iran, Iraq, Pakistan, Poland, Romania, Russia, Slovakia, and Thailand [SAS (2004, pp. 35–37, especially Table 1.11)].

well regulated (a grey market), and the arms may be imported altogether illegally into the ultimate recipient state (a black market). One commentator writes that the market relies as much on powerful law-breakers as on weak law-makers [Bourne (2005)]. For example, only 25 states have implemented explicit laws or regulations regarding arms brokering [SAS (2004, pp. 142, 161)], and they differ widely in reporting requirements, monitoring, verification, compliance, and enforcement. At the international level, only in July 2001 did some member states of the United Nations agree on a "Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects". Biennial meetings of states in 2003 and 2005 have resulted in limited progress on agreed-upon actions. The overall regulatory environment remains weak. There would be opportunities to apply economic theory developed with regard to other global challenges, say on international environmental regulation, to the case of international arms trade regulation but this does not appear to have been done to date [see, e.g., Sandler (1997)].

3.4. *The demand for small arms and light weapons*

Until the mid-2000s, the SALW demand side was ignored with virtually no economics papers available even as the standard neoclassical theory of consumer demand suffices to generate a first cut at understanding the demand side.[28] At the level of the individual, the primary determinants of demand are preferences, resources, and the prices of SALW and their complements and substitutes.[29] To understand why people acquire small arms is as important as to understand why they do not. From the difference in the choice behavior we may expect to learn what accounts for the switched state. For example, the removal of certain constraints associated with the end of apartheid in South Africa in 1994 unleashed an explosive expression of previously "hidden" demand for small arms. This has been difficult to reverse. In contrast, some communities have been penetrated with arms to only a small extent [e.g., Kyrgyzstan; see SAS (2004, chapter 10)].

A gun is most "productive" in defensive or predatory situations when it is cycled among several users, but groups of people (families, clans, gangs, police forces, etc.) must develop an effective internal control mechanism to prevent gun abuse within the group. Research on how groups maintain internal cohesion and prevent within-group gun abuse may provide important clues to unraveling SALW demand in larger social entities. The huge literature on the economics of crime has yet to be exploited to learn what lessons may be transferable to the small arms demand research field [see, e.g., Cook and Ludwig (2000), Hemenway (2004)].

Final demand for self-defense, recreation, or sport-hunting purposes needs to be separated from derived demand by those for whom weapons are an input into the production of goods or services such as commercial hunting, pest-control, or security services, or the production of disservices such as banditry. These broad categories of demanders should not be conflated, not only because the underlying preferences differ but also because the means both groups bring to bear on demand are vastly different. We would expect gun collectors for instance to finance gun acquisition from earned income or by trading one asset for another, e.g., to liquidate financial holdings for a gun collection, hoping that the latter will appreciate faster than the former. Consumers need to consider the tradeoff of resource expenditure on a gun to resource expenditure on other goods and services. Thus, even in the presence of high motivation, limited resources and high gun (or ammunition) prices erect an effective barrier to acquisition. In contrast, producers, e.g., those with the intent to abuse small arms for criminal purposes, view guns as a tool that earns a return on investment. Thus, the demand for small arms by these two groups of acquirers would be expected to follow markedly different trajectories and dynamics. Theory would also suggest that producers of armed violence would search more actively than final demanders for improved technologies of violence – hardier, lighter, more easily concealed, and more powerful firearms. Effective regulation of a bad or disservice requires a capable and effective enforcement apparatus, but it is precisely the absence of this apparatus that provides the space that brings producers of violence into sustained existence.

Demand-related basic data collection and empirical studies have been carried out only as from the mid-2000s, primarily as case studies commissioned by the Small Arms Survey. Field-based research has been planned for a number of non-high income states, e.g., Burundi, Congo-Brazzaville, Macedonia, and Sudan, and initial research has been completed for non-high income states such as the Brazil, Papua New Guinea, the Solomon Islands, and South Africa [Nelson and Muggah (2004), Muggah (2004), Kirsten et al. (2004), Lessing (2005)]. Each case highlights different aspects of how motivations and means combine to stimulate or inhibit small arms acquisition or (ab)use. For example, in Papua New Guinea (PNG) the comparatively recent arrival and use of modern firearms has escalated traditional forms of violent conflict to levels that threaten to exceed local capacities to cope. While the range of types of firearms is surprisingly diverse, field study found that the numbers of such arms are comparatively modest, at least in part because of unusually high ammunition prices. This is an intriguing finding as it points to the possibility that at least in some cases policy intervention may most usefully focus not on firearms *per se* but on the supply-chain or on complementary products and services [SAS (2005, chapter 1)].

Field research has also documented interesting dynamics of local trade in small arms. In PNG, income and assets of various types (e.g., pigs, crops, and women) were found to be exchanged for firearms. Thus, the means of small arms acquisition refer not only to the exchange of earned income for arms but include grants, loans, and the depletion of unusual assets. Further, key informant interviews in PNG revealed weapon acquisition not only by individuals but also by village or tribal collectives, and surveys showed that tribes would readily rent weapons, or the services of mercenaries, to pursue violent armed conflict with neighbors. Given their high motivations and limited means, the

[28] This section relies on Brauer and Muggah (2006).

[29] Collier et al. (2003) discuss demand factors such as the relation of natural resource wealth to civil war and hence small arms demand.

tribes display sophisticated choice behavior to achieve their objectives. The endemic nature of violence among PNG tribes may reduce the likelihood of success for individual preference or motivations-based demand intervention. Rather, in this case initiatives may be more successful if they focus resources on raising the price of firearms, ammunition, and related repair and service, as well as raising the price of firearm (ab)use through strict and accountable law enforcement, a strategy that appears to have bourne some fruit in the Solomon Islands [see Brauer and Muggah (2006)].

Data on the distribution of SALW by user category is difficult to come by, mostly because estimation of ownership by unregistered and/or illegal owners involves large uncertainties. To cite just one example, for 2003 for 11 Latin American states one estimate suggests 8.8 million firearms in possession by uniformed (military and police) forces. This contrasts to 11.6 million civilian registered firearms and an additional estimated 25 to 60 million civilian unregistered firearms [SAS (2004, Table 2.2, p. 51)]. Similarly lop-sided distributions are obtained virtually whenever an estimate is attempted. Overall, the civilian market is estimated at 80 percent of the overall market [SAS (2004, p. 21)].

In sum, the SALW market has not been well examined theoretically or empirically. Nor is the raw material of underlying data conducive to testing whatever hypotheses theory might generate. Diplomats' work has focused – as for the case of the other weapons classes – on supply-side regulation such as arms trade and weapons registries and non-proliferation schemes. Unfortunately, as production technologies migrate, the states with the weakest capacity to create and enforce supply-side regulations are also the states where most of the SALW problems lie. This does not make supply-side research superfluous – it is certainly worth learning more about the mechanics of the diffusion of weapons production and trade and associated complements – but if effective small arms and violence control policies are to be found, research on the demand-side as well as on intermediate markets along the supply-chain will have to play a much bigger part than has been the case thus far.

4. Non-conventional weapons

4.1. Atomic weapons

A number of non-high income states are or have been engaged in the production of atomic, biological, and chemical – or ABC – weapons.[30] Economic information beyond basic count data (who produces what) is scant. For example, a certain well-stocked

[30] Atomic weapons belong to the larger rubric of radiological weapons. A radiological weapon is any combination of an agent and a distribution device capable of causing radiological contamination. Thus defined, release of any radioactive material (e.g., materials used in nuclear medicine) through any distribution device (e.g., dynamite) would count as a radiological weapon. In practice, such weapons still are restricted to atomic bombs, hence the limitation in this section on these weapons.

defense academy library carries over a dozen books on Pakistan's atomic program – half of them published in Pakistan – but in none of them does one find any reasonably derived program cost or budget information. One estimate, based on United Nations Special Commission (UNSCOM) mission data for Iraq, puts Pakistan's annual cost for its program, started in 1972, at between US$500–700 million, not counting the cost for delivery systems [Mian (1995, p. 63)]. Even an up-to-date encyclopedia on weapons of mass destruction [Croddy, Wirtz and Larsen (2005)], while carrying information on actual weapons and delivery types and technology, carries virtually no economic content. One can conclude only that when states do demonstrate possession of non-conventional weapons they have obviously achieved their production – at whatever cost. Regarding trade, spectacular information comes to light occasionally, as when Pakistan's Abdul Qadeer Khan's illicit nuclear proliferation network was exposed in 2003. As for the case of major conventional weapons, an arms embargo spurs the drive to find substitute suppliers. For example, Pakistan first approached the United States to acquire facilities to produce weapons-grade plutonium. Rebuffed, Pakistan redirected its efforts and eventually succeeded with technical assistance from China and North Korea and financial assistance by Libya and Saudi Arabia [Lavoy (2005, pp. 275–276)]. Abdul Qadeer Khan received training in Germany, and Germany and Canada provided pre-cursor nuclear technology [Langford (2004, p. 72)]. And US-supplied F-16 and French-supplied Mirage-5 jets provided the weapons-delivery capability. But because of an embargo placed on the F-16 in 1990, Pakistan substituted these by commencing its ballistic missile program, again with Chinese and North Korean help. By 2005, more than two dozen nations were in possession of ballistic missiles and, although an old design, almost 30 states had either purchased the SCUD missile or purchased the underlying technology to develop their own versions.

A similar story can be told for South Africa which, under an international arms trade ban, developed its own atomic weapons capability, using pre-cursor technology from the United States and France. The United States detected a low-yield, high-altitude nuclear explosion off South Africa's coast in 1979 but programs details, including suspected atomic trade relations to Israel, are unknown. South Korea also dabbled in atomic weapons manufacture but abandoned its efforts under US pressure in 1972. India's atomic program was built with pre-cursor assistance from Canada, France, Russia, and the United States. As for the case of South Africa, many of its scientists were US trained [Langford (2004, pp. 70–72)]. Before it was expelled from Iraq, UNSCOM documented Iraqi trade in atomic weapons-related equipment and physically destroyed or removed 48 operational missiles, six operational mobile launchers, 28 operational fixed launch pads, 32 fixed launch pads under construction, and other missile support equipment and materials [Segell (2005, p. 390)]. While Iraq's program strained its industrial capacity, it was able to acquire by trade much preparatory material although at unknown cost.

According to the Nuclear Threat Initiative, the following current or former non-high income states have or have had weapons-related atomic programs or functional atomic weapons: Argentina, Belarus, Brazil, China, Egypt, India, Iran, Iraq, Israel, Kazakhstan, Libya, North Korea, Pakistan, Russia, South Africa, South Korea, Taiwan, Ukraine, Uzbekistan, and Yugoslavia.[31] Of these, Argentina, Brazil, Iraq, Libya, South Africa, South Korea, and Taiwan have withdrawn from their respective efforts[32]; Israel has never publicly acknowledged such production; Iran's efforts are widely rumored but not factually confirmed; North Korea has announced possession of atomic weapons and appears to have carried out a nuclear test explosion in October 2006; and China, India, and Pakistan all have tested atomic weapons and are known to possess delivery vehicles and targeting technology. The latter – delivery and targeting – are complementary to atomic weaponry and constitute a substantial technological hurdle to overcome (see Section 4.4).

While supply-side control of critical input technologies has slowed weapons proliferation, the idea of non-proliferation does not appear to have worked. Under perceived duress or threat even states with scant industrial and human resources have made obvious progress toward the production of such weapons. Entry into this industry is possible, even if at unknown but probably enormous cost, perhaps explaining why some states have chosen to exit this segment of the market (Brazil, Libya, and South Africa) or to rid themselves of their inheritance (Belarus, Kazakhstan, Ukraine) when their political situation and threat perception changed.

4.2. *Biological weapons*

Regarding biological weapons, 147 states are party to the 1972 Biological and Toxin Weapons Convention (BTWC). Entered into force in 1975, it prohibits the development, production, and stockpiling of biological weapons (BW). Some states have signed but not ratified the BTWC, e.g., Syria. Unlike the CWC (see Section 4.3), the treaty does not provide for a verification protocol, and it is not anticipated that such will be achieved during the next 10 or 20 years. This has led states to engage in confidence-building measures and to invest in biosecurity initiatives. Confidence-building measures include annual declarations and reports regarding high-risk facilities, outbreaks of unusual diseases, promotion and publication of relevant research, and cross-state scientific interaction. However, since 1986 fewer than 40 states regularly issue such declarations, with most non-high income states abstaining [Croddy (2005a, pp. 43–47)].

Iran, Iraq, Libya, South Africa, and the former Soviet Union are known to have developed and/or used biological weapons. India is known to possess a defensive bioweapons

[31] Syria is sometimes alleged to be among this group, but according to the Nuclear Threat Initiative there is no evidence to support this assertion. The evidence regarding Egypt is only slightly stronger. For all other states mentioned, the programs and/or weapons are either publicly known or else the evidence is deemed compelling.

[32] On 7 August 2005, former Brazilian President Jose Sarney publicly acknowledged that Brazil had an active atomic weapons program under its military dictatorship phase, 1964–1985. This was Brazil's first public acknowledgment of its erstwhile program (Andrew Hay, Reuters news story, 8 August 2005). Three weeks later, Jose Luiz Santana, former president of Brazil's nuclear energy commission publicly stated that the military were "preparing a test explosion" when the program was stopped and dismantled in August 1990 (Michael Astor, Associated Press news story, 30 August 2005).

research program. BW activity is alleged for China, Cuba, Egypt, and North Korea. Of the Soviet follow-on states, Belarus, Ukraine, and Uzbekistan have eliminated or are eliminating BW sites. The situation in Kazakhstan is unclear.[33] Brazil, Pakistan, and Russia have undisputed BW potentials but there is no convincing evidence that this has been used to research or manufacture BW agents. On Syria's and Taiwan's BW intentions and/or capabilities there are conflicting reports.

Today, the only practical (efficient) mass-dispersal method of delivering biological weapon agents – i.e., bacteria, viruses, and toxins – is thought to be through the use of infectious aerosols. But processing of biological materials to requisite diameters of between 1 and 10 microns, while maintaining viability in storage and dispersal, is considered to be "technically demanding" [Croddy (2005b, p. 53)]. Small-scale biological weapons production probably does not lie beyond the scientific and industrial capabilities of certain non-high income state-actors but as yet appears to carry little military or diplomatic value as compared to alternative applications of scarce military-related resources.

4.3. *Chemical weapons*

The Organization for the Prohibition of Chemical Weapons (OPCW) implements the provisions of the 1993 Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on their Destruction (CWC, for short).[34] As of 31 December 2004, 167 states have ratified the treaty. Among non-signatories are Egypt, Iraq, North Korea, and Syria. Of these, Iraq and Syria are known to have acquired (the latter through Egypt), produced, and/or used chemical weapons. So has Libya, but on 19 December 2003 it renounced the production and use of weapons of mass destruction and signed the CWC in 2004 (it still needs to ratify the treaty). Israel has signed but not ratified the treaty. The CWC includes an "anytime, anywhere" inspection provision and as of December 2002, 1,276 inspections at 5,237 declared sites had been carried out. Five states declared possession of chemical weapons stockpiles, to be destroyed within 10 to 15 years. By early 2005, twelve CWC members had declared more than 60 former chemical weapons production facilities; ten states declared possession of "old", i.e., pre-1946, chemical weapons; and three declared harboring "abandoned" chemical weapons deposited there by other states party to the CWC (the largest, over a million munitions, by Japan in China).[35]

[33] It has received United States funding to dismantle sites but still holds "extensive collections of virulent strains of human, animal, and plant pathogens" [Nuclear Threat Initiative; www.nti.org (accessed 31 August 2005)].

[34] Explosives are chemical weapons of course but are not covered by CWC. Military analysts consider thermobaric (fuel–air) explosives used by the United States and Russia (e.g., in the 1990s in Iraq and in Chechnya, respectively) as equivalent to low-yield tactical nuclear weapons [Clark (2005)]. Likewise, atomic weapons rely on physical properties (e.g., shockwaves) of chemical reactions and are not considered chemical weapons.

[35] Declared stockpiles: in Albania, the United States, Russia, India, and South Korea; former production facilities: in Bosnia-Herzegovina, China, France, India, Iran, Japan, Libya, Russia, Serbia and Montenegro,

Although there are limitations on what must be declared, and vigilance must be maintained regarding future chemical weapons production, it is generally thought that the CWC and its supervision, advice, and inspection regime work well.[36] The OPCW secretariat has about 500 employees and, for 2005, a €75 million budget [Hart (2005, pp. 93–96), SIPRI (2005, chapter 13)]. Nonetheless, a report in *Science* expresses concern about rapidly advancing production technology, such as "miniaturized reaction systems for chemical synthesis and production ... [with] dimensions ranging from credit card size to notebook size" [Nguyen (2005, p. 1021)]. Several lethal compounds are known to have been produced in this way. Chemical warfare agents are grouped into choking, blister, blood (systemic), and nerve agents. Other agents, such as incapacitants (riot-control agents), are considered non-lethal in the intended dosage. Their use as a method of warfare is forbidden under the CWC.

Little is known about production and delivery costs of biological and chemical weapons but as compared to atomic weapons they are generally believed to be easier and cheaper to produce. However, this does not necessarily make it easier or cheaper to deliver such weapons. For long-distance regional or intercontinental ballistic missile use for instance, in addition to solving the same long-distance delivery problems as for atomic weapons, biological agents will need to be suitably refrigerated and protected during re-entry and subsequent high-speed dispersal. Heat generated during an explosion can destroy biological or chemical agents. To prevent this, complex spray dispersal methods are needed. Furthermore, unlike for the case of atomic explosions, suitable meteorological and topological conditions must be present for CBW agents to bring about the intended effects. Some analysts thus believe that the operational utility of CBWs for state actors in state-on-state warfare is questionable [Enders and Sandler (2006), Davis (2005, p. 85), Spiers (2000, pp. 57–75)]. The general absence of their use by state actors in war is indicative.[37] However, studies in the operational use of non-conventional weapons for small-scale use in geographically limited environments (e.g., points of troop disembarkation) are advancing rapidly and are in the public domain. Combined with equally rapidly developing molecular biology, chemical, and delivery-technology engineering knowledge and its dispersion through open-access science has analysts concerned that substitution into asymmetric weaponry by non-high income states and non-state actors is attractive, even likely. The more overwhelming a potential adversaries' conventional force advantage, the more compelling the option to substitute into alternative weaponry becomes. The binding constraint appears to be neither cost nor production capability but organizational and statutory: the development of a new warfare doctrine using cheap, novel, and unconventional weaponry might require a complete overhaul of the armed services partition into army, navy, and air force and would probably require formal withdrawal from the BTWC and CWC that most, but not all, states have signed and ratified.

The weapons are also attractive for state covert operations. South Africa's Project Coast (later, Project Jota) included one CW and one BW production site, the former with 120 staff members, the latter with 70. Work focused on chemical incapacitants and bioregulators to affect physiological function. The resulting agents are suspected to have been employed in Mozambique and Namibia, border states to South Africa, but the most direct application is reported to have been the use of hard-to-trace agents against individual "enemies of the state" [Bale (2005, p. 268)].

South Korea, the United Kingdom, and the United States; possession of pre-1946 CW: in Australia, Belgium, Canada, France, Germany, Italy, Japan, Slovenia, the United Kingdom, and the United States; abandoned CW: in China, Italy, Panama.

[36] Intransigent states such as Iran (atomic weapons), Iraq (atomic, biological, and chemical weapons), and North Korea (atomic weapons) can obviously delay inspection regimes which increases the burden placed on the reliability of intelligence information.

[37] Libya's prime minister reportedly cited ABC-program cost as compared to the expected military and political benefit of the resulting weapons as the reason for the country's 19 December 2003 decision to renounce weapons of mass destruction; similarly Gaddafi in a *Le Figaro* interview in November 2004 [SIPRI (2005, pp. 633–634)].

4.4. *Missile technology and space-based activities*

A complement to work on atomic and, although to a lesser extent, biological and chemical weapons is work on delivery technology, especially but not only with regard to missiles and missile technology. States such as Brazil, China, India, North Korea, Pakistan, Russia, and South Africa have been able to make substantial indigenous strides in this regard. Some of them have rendered assistance to states such as Syria that are thought to have tried but been unable to produce missiles with completely indigenous resources. Having no illusion about the outcome if it became entangled in a conventional war with Israel, Syria has the motivation to develop alternative war-fighting means. Yet despite 30 years of effort, it apparently does not possess the economic wherewithal to do so. Comparing Syria to states that have had a measure of success, such as Iraq, might make it possible to deduce, at least qualitatively, the relevant success threshold even in the absence of specific weapons-related cost and production data.

Cost (or export revenue) information on ballistic missiles is not reliably available. SIPRI notes scattered prices, mostly below US$2 million per unit. For these missiles, however, pay-load is small and target inaccuracy high. When fitted with conventional warheads, the weapons would therefore not be suitable for war-fighting, and their value may be psychological rather than military [SIPRI (2004, pp. 554–555)]. Fitted with ABC-weapons, target accuracy becomes less important. But if fitted with accurate guidance systems, ballistic missiles with conventional warheads become more valuable. It is generally held that such systems will shortly become widely available at commercial (i.e., market-based competitive) prices. Still, missiles are complicated devices requiring a host of inputs such as special fuels, engines, warheads, re-entry vehicles, and guidance systems so that competitive exports by non-high incomes states may yet lie a while into the future.

Quite a bit of information on non-high income states' space-related production activities is available but it is scatted and unsystematic. This information rarely comes with any sort of cost figures or information regarding human and physical input requirements. Only three states – China, Russia, and the United States – have active military space programs and only the United States has the capability to weaponize satellites. This requires expensive logistics that presently no state other than the United States can afford [UNIDIR (2003, p. 6)]. Still, as has been the case for conventional weapons, "rapid growth in commercial space activities and the inherently dual-use nature of most space systems" [Hays (2003, p. 22)] will increasingly subject space to economies of scale and scope and hence primarily to economic rather than to political opportunities and constraints. For example, high-resolution space-based photography is readily and cheaply available from the commercial sector, whereas only a few years ago use of such intelligence assets were restricted to the then-superpowers. Thus the militarization of space – the use of outer space for military purposes – if not the weaponization of space is already happening.

A typology divides military space missions into (a) space support, (b) force enhancement, (c) space control, and (d) force application missions [Hays (2003)]. By the mid-2000s, no state has deployed weapons in space, nor can any assert control of outer space (the ability to deny military use of space to others). But a number of states have developed or are developing space support infrastructure to use space for force enhancement, e.g., for integrated tactical warning and attack assessment and for intelligence, surveillance, and reconnaissance, and of course for communications, position, velocity, time, and navigation (GPS) purposes.

Thirty-seven current or former non-high income states possess agencies, corporations, or facilities related to commercial, civilian, or military use of outer space.[38] Many of the uses are for communication, navigation, and earth observation rather than for military purposes and involve shared or cooperative ventures. For example, Nigeria launched its first satellite in September 2003. While it provided little more than the money, it is indicative of the globalized nature of even this market that it could purchase the United Kingdom-built satellite and have it launched from Russia. Brazil curtailed its ballistic missile research in the early 1990s and joined the Missile Technology Control Regime but continues research on space launch vehicles. While much current space-activity of non-high income states in benign, there is no doubt that at least some of the current activity can be switched to military purposes.

4.5. ABC-weapons production and entry/exit theory

In the Cold War context, theoretical work was primarily directed toward nuclear arms races and their threatened use, but this presumed the physical existence of the weapons

[38] They are: Algeria, Azerbaijan, Brazil, China, the Czech Republic, Egypt, Hungary, India, Indonesia, Iran, Iraq, (Israel), Lebanon, Malaysia, Morocco, Nigeria, North Korea, Pakistan, the Philippines, Peru, Poland, (Portugal), Russia, (Saudi Arabia), (Singapore), Slovakia, (Slovenia), South Africa, (South Korea), (Spain), Syria, (Taiwan), Thailand, Tunisia, Turkey, Ukraine, and Uruguay. See www.globalsecurity.org [accessed 17 September 2005]. Former non-high income states are listed in parentheses.

[see, e.g., Brito and Intriligator (1995)]. The post-Cold War atomic weapons economics literature with regard to non-high income states is relatively thin. Singh and Way (2004) test a "theory of proliferation" with a model whose empirical variables include domestic political factors, the external security environment, and economic variables such as industrial capacity. Instead of a binary dependent variable, the option to "go nuclear" is stratified into four stages: (a) no interest in atomic weapons efforts, (b) exploration of an atomic weapons option, (c) active pursuit of atomic weapons acquisition, and (d) actual production of one or more atomic weapons. Covering 154 states with data from 1945 to 2000, ideally the model would predict not only the states interested in atomic weapons but also the time-path of the nuclear-weapons stage or stages any specific state may have taken. Despite some prediction misses, the model does a credible job of identifying which state enters which stage at which time. In particular, the model identifies threat perceptions (motivations) and industrial capacity (means) as the drivers in the decision to acquire atomic weapons. Not all states with the means to "go nuclear" have the motivation to do so; conversely, and worryingly, some states with the motivation to acquire nuclear arms may, in future, arrive at the means to do so.

The Singh and Way paper is a theory of entry, not of exit. Why and how a state may choose to dispose of nuclear weapons is not modeled [Singh and Way (2004, p. 883)]. Exit is modeled, even if only incidentally so, for the case of Ukraine in a paper by Jehiel, Moldovanu and Stacchetti (1996). Ukraine disposed of its nuclear inheritance by negotiations that matched the projected maintenance cost with dismantlement "aid" it could extract from Russia and the United States as against potential proliferation offers from other bidders. Part of the vertical contracting literature, the model captures a situation in which "buyers have preferences over which other agents may get the good" [Jehiel, Moldovanu and Stacchetti (1996, p. 815)] and asks about the optimal selling strategy when the ultimate buyer's acquisition generates negative externalities for non-buyers. For example, if Iran had bought Ukrainian atomic weapons, a negative externality would have been created for neighbors such as Iraq. One result of the model is that the seller can credibly commit not to sell at all. Instead of selling weapons, Ukraine sold dismantlement. The scenario is at least superficially similar to that of environmental protection groups purchasing pollution credits with the objective of removing them from circulation or of conservation societies purchasing patches of rainforest to withdraw them from potential cultivation.

Still, almost no theory work has been done with regard to the underlying production issues that bring atomic weapons into existence. One paper [Koubi (1999)] – based on the commercial R&D and patent literature – develops a three-stage military R&D race model. An important aspect of the model is that states are posited to monitor and react to their *relative* position in the race, as the outcome of the race carries implications for the distribution of military power. Unlike some commercial R&D races in which a winner-takes-all outcome may induce the losing competitor to switch resources into *another* R&D project, in the military R&D race there can be important benefits for the loser to catch up with the winner. Thus, the dynamics of the military race differ from that of the commercial race. In Koubi's model, the loser thus never concedes.

Instead, it intensifies its efforts the further behind it falls. Moreover, so long as any benefit is derived from eventual success, independent of the order of arriving at the finish line, a state will not unilaterally withdraw from the race [Koubi (1999, p. 545)].[39] An interesting application concerns the nuclear arms efforts in the non-high incomes states of China, India, and Pakistan. While the Indo-Pakistani nuclear test explosions in 1998 refocused world attention on that pair of states, India's policy is directed elsewhere: its efforts are not aimed at increasing the distance to Pakistan but at catching up with China, the more so since China assisted in the development of Pakistan's nuclear arsenal [Singh (1998)]. Koubi's model implies that if China races to catch up to the United States – possibly to snare Taiwan as the prize – then India races to catch China, and Pakistan races to catch India. Instead of viewing arms races as an n-state race where $n = 2$, as much of the literature has done (e.g., Greece–Turkey, or India–Pakistan), such races might better be viewed as n-state races where $n > 2$.

In sum, while some threat of development of biological and chemical weapons by non-high income state-actors remains, the major threat lies in the continuation of attempts to research, develop, and deploy atomic weapons atop ballistic missiles. The record is too faint to ascribe costs to the effort non-high income states undertake. But the record is clear in indicating several aspects of interest: (a) proliferation of atomic weapons-related technologies does take place; (b) some non-high income states successfully enter the industry; (c) atomic weapons arms races between and among non-high income states do take place; and (d) some non-high income states exit the atomic weapons industry, possibly irreversibly. As yet, a theory that would account for all four of these facts does not appear to have been formulated [Singh and Way (2004)].

5. Conclusion

Several themes emerge from the foregoing pages. First, data availability is poor for major conventional weapons, poorer for small arms and light weapons, and poorest for non-conventional weapons. Second, theory is not well developed regarding arms production and arms trade activities of non-high income states. An effort has been made here to show that models from outside the defense economics literature may be brought to bear to the subject matter: the vertical boundaries of the firm, the product life-cycle hypothesis, and the vertical contracting and R&D patent-race examples employed in this chapter all come from within the literature on the theory of the firm. Perhaps other field literatures may be parsed and tapped in a similar manner. Third, just as former non-high income states such as Greece, Israel, Portugal, Singapore, South Korea, Spain, and

[39] Koubi's model precludes consideration of a preemptive strike by the military R&D winner since this would be equivalent to a commercial winner-takes-all scenario. In this scenario, the loser is better off to stop its own efforts and redirect resources to another race. However, an avowed and credible *policy* of preemption may discourage laggards in the race from pursuit, or otherwise diminish laggards' intensity of effort, a scenario that may apply to the Middle East [Koubi (1999, p. 551)].

Taiwan graduated from low-level conventional arms production to become producers of reasonably sophisticated platforms, components, weapons, and weapon systems, so now we stand on the threshold of a number of current non-high income states being able to graduate toward the production of similarly advanced weapons. What might give pause is that the aforementioned set of states consists of small populations of inherently small economic and military weight. In contrast, current non-high income states such as Brazil, China, India, Indonesia, Malaysia, Pakistan, Russia, and South Africa pack much more potential economic and military weight. Economies of scale and scope may assume a more important role in arms production and trade dynamics than before as the internal market of these countries might now compete with those of the United States or of the European Union.

Fourth, although non-proliferation regimes have slowed weapons (or precursor-technology) proliferation, they have failed to stop it. Supply-side restrictions do not overcome demand-side pressures. We observe industry entry in all weapons categories and in future may expect to see further increases in industry participation by non-high income states, even if in a different form than hitherto (e.g., more cross-border integration of supply-chains). This is the natural consequence of the gradual development of states' human, physical, and institutional capital, i.e., the development of their production capacities. Given the means, all that is required is a motive to engage in indigenous arms production. This, fifth, puts an increasing burden on the quality of world diplomacy. The more readily available are the means to fight, and the more these means migrate to non-high income states and non-state actors, the more urgent for research and policy to address the formation of conflict-preferences and to study the design of effective self-policing or intervention mechanisms. Sixth, while all states benefit from the mutual production of mutual security, only in the rarest cases can it be said that non-high income states derive specific economic benefits from weapons production and associated trade.

References

Alexander, A.J., Butz, W.P., Mihalka, M. (1981). "Modeling the production and international trade of arms: An economic framework for analyzing policy alternatives". RAND Note N-1555-FF/RC. RAND, St. Monica, CA.
Anderton, C.H. (1995). "Economics of arms trade". In: Hartley, K., Sandler, T. (Eds.), Handbook of Defense Economics, vol. 1. North-Holland, Amsterdam, pp. 523–561.
Anderton, C.H. (1996). "What can international trade theory say about conventional arms trade?". Peace Economics, Peace Science and Public Policy 4 (1–2), 9–31.
Bale, J.M. (2005). "South Africa: Chemical and biological weapons programs". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 266–269.
Baskaran, A. (2004). "The role of offsets in Indian defense procurement policy". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development: Theory, Policy, and Cases in Arms Trade Offsets. Routledge, London, pp. 217–232.
Bauer, S. (2006). European Arms Export Policies and Democratic Accountability. Oxford University Press, Oxford.

Besanko, D., Dranove, D., Shanley, M., Schaeffer, S. (2004). Economics of Strategy. Wiley, New York.

[BICC] Bonn International Center for Conversion (2003). Conversion Survey. Nomos, Baden-Baden.

Bitzinger, R.A. (1994). "The globalization of the arms industry: The next proliferation challenge". International Security 19, 170–198.

Bitzinger, R.A. (2003). Towards a Brave New Arms Industry? Oxford University Press, Oxford.

Bourne, M. (2005). "The proliferation of small arms and light weapons". In: Krahmann, E. (Ed.), New Threats and New Actors in International Security. Palgrave, New York, pp. 155–176.

Brauer, J. (1991). "Arms production in developing nations: The relation to industrial structure, industrial diversification, and human capital formation". Defence Economics 2, 165–175.

Brauer, J. (2000). "Potential and actual arms production: Implications for the arms trade debate". Defence and Peace Economics 11, 461–480.

Brauer, J. (2002). "The arms industry in developing nations: History and post-cold war assessment". In: Brauer, J., Dunne, J.P. (Eds.), Arming the South: The Economics of Military Expenditure, Arms Production, and Arms Trade in Developing Countries. Palgrave, New York, pp. 101–127.

Brauer, J., Dunne, J.P. (Eds.) (2002). Arming the South: The Economics of Military Expenditure, Arms Production, and Arms Trade in Developing Countries. Palgrave, New York.

Brauer, J., Dunne, J.P. (Eds.) (2004). Arms Trade and Economic Development: Theory, Policy, and Cases in Arms Trade Offsets. Routledge, London.

Brauer, J., Muggah, R. (2006). "Small arms demand: Theory and initial evidence". Contemporary Security Policy 27 (1), 138–154.

Brito, D., Intriligator, M. (1995). "Arms races and proliferation". In: Hartley, K., Sandler, T. (Eds.), Handbook of Defense Economics, vol. 1. North-Holland, Amsterdam, pp. 109–163.

[BVC] Bureau of Verification and Compliance (2002). World Military Expenditures and Arms Transfers, 1999–2000. Bureau of Verification and Compliance, US Department of State, Washington, DC.

[BXA] Bureau of Industry and Security (2005). Offsets in Defense Trade, Ninth Study. Bureau of Industry and Security, US Department of Commerce, Washington, DC.

Cavicchia, G.P. (2003). "The dismantling of the Argentine defense industry". In: Markusen, A., DiGiovanna, S., Leary, M.C. (Eds.), From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London, pp. 101–120.

Chen, S. (2003). "Defense conversion in China". In: Markusen, A., DiGiovanna, S., Leary, M.C. (Eds.), From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London, pp. 201–223.

Clark, W.S. (2005). "Fuel-air explosive (FAE)". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 136–137.

Coase, R. (1937). "The nature of the firm". Economica 4 (16), 386–405.

Collier, P., Hoeffler, A. (2007). "Civil war". In: Sandler, T., Hartley, K. (Eds.), Handbook of Defense Economics, vol. 2. North-Holland, Amsterdam. This volume.

Collier, P., Sambanis, N. (2005). Understanding Civil War: Evidence and Analysis. World Bank, Washington, DC.

Collier, P., et al. (2003). Breaking the Conflict Trap: Civil War and Development Policy. World Bank and Oxford University Press, Washington, DC.

Conca, K. (1998). "Between global markets and domestic politics: Brazil's military-industrial collapse". Review of International Studies 24, 499–513.

Cook, P., Ludwig, J. (2000). Gun Violence: The Real Costs. Oxford University Press, Oxford.

Cooper, N. (2006). "Peaceful warriors and warring peacemakers". Economics of Peace and Security Journal 1 (1), 20–24.

Croddy, E.A. (2005a). "Biological and toxin weapons convention (BTWC)". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 43–47.

Croddy, E.A. (2005b). "Biological warfare". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 50–59.

Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.) (2005). Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History. ABC-Clio, Santa Barbara, CA. 2 vols.

[CRS] Congressional Research Service (2005). Conventional Arms Transfers to Developing Nations, 1997–2004. Congressional Research Service, Washington, DC.

Dando, M. (2002). "Scientific and technological change and the future of the CWC: The problem of non-lethal weapons". Disarmament Forum 4, 33–44.

Dando, M. (2005). "The malign use of neuroscience". Disarmament Forum 1, 17–24.

Davis, M. (2005). "Chemical and biological munitions and military operations". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 80–85.

Duffield, M. (2001). Global Governance and the New Wars: The Merging of Development and Security. Zed Books, London.

Dunne, J.P. (1995). "The defense industrial base". In: Hartley, K., Sandler, T. (Eds.), Handbook of Defense Economics, vol. 1. North-Holland, Amsterdam, pp. 399–429.

Dunne, J.P., Lamb, G. (2004). "Defense industrial participation: The South African experience". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development. Routledge, London, pp. 284–298.

Dunne, J.P., Surry, E. (2006). "Arms production". In: SIPRI Yearbook. Oxford University Press, Oxford, pp. 387–418.

Enders, W. (2007). "Terrorism: An empirical analysis". In: Sandler, T., Hartley, K. (Eds.), Handbook of Defense Economics, vol. 2. North-Holland, Amsterdam. This volume.

Enders, W., Sandler, T. (2006). The Political Economy of Terrorism. Cambridge University Press, Cambridge.

Florquin, N. (2005). "Guns in crime". HFG Review: 21–25. http://www.hfg.org/hfg_review/5/hfgsmallarms.pdf [accessed 11 September 2005].

García-Alonso, M., Levine, P. (2007). "Arms trade and arms races: A strategic analysis". In: Sandler, T., Hartley, K. (Eds.), Handbook of Defense Economics, vol. 2. North-Holland, Amsterdam. This volume.

Godnick, W., Laurance, E.J., Stohl, R., Small Arms Survey (2005). "Effects of small arms misuse". HFG Review: 10–20. http://www.hfg.org/hfg_review/5/hfgsmallarms.pdf [accessed 11 September 2005].

Hart, J. (2005). "Chemical weapons convention (CWC)". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 93–96.

Hartley, K. (2007). "The arms industry, procurement and industrial policies". In: Sandler, T., Hartley, K., (Eds.), Handbook of Defense Economics, vol. 2. North-Holland, Amsterdam. This volume.

Hays, P.L. (2003). Current and future military uses of space. In: United Nations Institute for Disarmament Research, Outer Space and Global Security. UNIDIR, Geneva, pp. 21–64.

Hemenway, D. (2004). Private Guns, Public Health. The University of Michigan Press, Ann Arbor, MI.

[IISS] International Institute for Strategic Studies (2004). The Military Balance, 2004–2005. Oxford University Press, London.

Jehiel, P., Moldovanu, B., Stacchetti, E. (1996). "How (not) to sell nuclear weapons". American Economic Review 86 (4), 814–829.

Kennedy, G. (1974). The Military in the Third World. Scribner's, New York.

Khakee, A., Wulf, H. (2005). "Following the trail: Production, arsenals, and transfers of small arms". HFG Review: 26–30. http://www.hfg.org/hfg_review/5/hfgsmallarms.pdf [accessed 11 September 2005].

Killicoat, P. (2006). "Cheap guns, more war? The economics of small arms". MPhil Economics Thesis. Oxford University.

Kirsten, A., Mashike, L., Matshedisho, K.R., Cock, J. (2004). "Islands of safety in a sea of guns". Mimeo. Small Arms Survey, Geneva.

Koubi, V. (1999). "Military technology races". International Organization 53 (3), 537–565.

Krause, K. (1992). Arms and the State: Patterns of Military Production and Trade. Cambridge University Press, Cambridge.

Langford, R.E. (2004). Introduction to Weapons of Mass Destruction: Radiological, Chemical, and Biological. Wiley–Interscience, Hoboken, NJ.

Laurance, E.J. (2005). "Small arms research: where we are and where we need to go". HFG Review: 3–9. http://www.hfg.org/hfg_review/5/hfgsmallarms.pdf [accessed 11 September 2005].

Lavoy, P. (2005). "Syria: chemical and biological weapons programs". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 1. ABC-Clio, Santa Barbara, CA, pp. 275–277.

Leander, A. (2005). "The market for force and public security: The destabilizing consequences of private military companies". Journal of Peace Research 42, 605–622.

Lessing, B. (2005). "A case study on firearms demand in Rio de Janeiro". Mimeo. VivaRio, Rio de Janeiro.

Lewer, N., Davison, N. (2005). "Non-lethal technologies – an overview". Disarmament Forum 1, 37–51.

Lewis, D.A. (2003). "Diversification and niche market exporting: The restructuring of Israel's defense industry in the post-Cold War era". In: Markusen, A., DiGiovanna, S., Leary, M.C. (Eds.), From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London, pp. 121–150.

Maheswhari, S. (2003). "Diversification of defense-based industries in India". In: Markusen, A., DiGiovanna, S., Leary, M.C. (Eds.), From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London, pp. 179–200.

Markowski, S., Hall, P. (2004). "Mandatory defense offsets – conceptual foundations". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development: Theory, Policy, and Cases in Arms Trade Offsets. Routledge, London, pp. 44–53.

Markusen, A. (1999). "The rise of world weapons". Foreign Policy 114, 40–51.

Markusen, A. (2004). "Arms trade as illiberal trade". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development. Routledge, London, pp. 66–88.

Markusen, A., DiGiovanna, S. (2003). "From defense to development?". In: Markusen, A., DiGiovanna, S., Leary, M.C. (Eds.), From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London, pp. 1–14.

Markusen, A., DiGiovanna, S., Leary, M.C. (2003). From Defense to Development? International Perspectives on Realizing the Peace Dividend. Routledge, London.

Mian, Z. (1995). "The costs of nuclear security". In: Mian, Z. (Ed.), Pakistan's Atomic Bomb and the Search for Security. Gautam Publishers, Lahore, pp. 39–81.

Muggah, R. (2004). "Diagnosing demand: Assessing the motivations and means for firearms acquisition in the Solomon Islands and Papua New Guinea". Technical Report Discussion Paper 2004/7. State Society and Governance in Melanesia Project, Research School of Pacific and Asian Studies. Australian National University, Canberra.

Mussington, D. (1994). Understanding Contemporary Arms Transfers. Brassey's, London.

Nelson, C., Muggah, R. (2004). Solomon Islands: Evaluating the Weapons Free Village Campaign. Small Arms Survey, Geneva.

Nguyen, T.H. (2005). "Microchallenges of chemical weapons proliferation". Science 309, 1021.

Perlo-Freeman, S. (2004). "Offsets and the development of the Brazilian arms industry". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development: Theory, Policy, and Cases in Arms Trade Offsets. Routledge, London, pp. 187–204.

Sandler, T. (1997). Global Challenges: An Approach to Environmental, Political, and Economic Problems. Cambridge University Press, Cambridge.

Sandler, T., Arce, D.G. (2007). "Terrorism: A game-theoretic approach". In: Sandler, T., Hartley, K. (Eds.), Handbook of Defense Economics, vol. 2. North-Holland, Amsterdam, This volume.

[SAS] Small Arms Survey (various years). "Small Arms Survey". Oxford University Press, Oxford.

Scheetz, T. (2004). "The Argentine defense industry: An evaluation". In: Brauer, J., Dunne, J.P. (Eds.), Arms Trade and Economic Development: Theory, Policy, and Cases in Arms Trade Offsets. Routledge, London, pp. 205–216.

Schwartz, A.N. (1987). "Arms transfers and the development of second-level arms industries". In: Louscher, D.J., Salomone, M.D. (Eds.), Marketing Security Assistance: New Perspectives on Arms Sales. Lexington Books, Lexington, MA, pp. 101–130.

Segell, G. (2005). "United Nations Special Commission on Iraq (UNSCOM)". In: Croddy, E.A., Wirtz, J.J., Larsen, J.A. (Eds.), Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History, vol. 2. ABC-Clio, Santa Barbara, CA, pp. 389–390.

Singer, P. (2005). Children at War. Pantheon, New York.

Singh, J. (1998). "Against nuclear apartheid". Foreign Affairs 77 (5), 41–52.

Singh, S., Way, C.R. (2004). "The correlates of nuclear proliferation". Journal of Conflict Resolution 48 (6), 859–885.

[SIPRI] Stockholm International Peace Research Institute (various years). SIPRI Yearbook: Armaments, Disarmament and International Security. Oxford University Press, Oxford.

Smith, R., Tasiran, A. (2005). "The demand for arms imports". Journal of Peace Research 42, 167–181.

Spiers, E.M. (2000). Weapons of Mass Destruction: Prospects for Proliferation. St. Martin's, New York.

Sprague, O. (2004). Lock, Stock, and Barrel: How British Arms Components Add up to Deadly Weapons. Oxfam, London.

Surry, E. (2006). "Transparency in the arms industry". SIPRI Policy Paper No. 12. Stockholm International Peace Research Institute, Stockholm.

[UK Government] Foreign and Commonwealth Office (2004). Response to Sprague, 2004. http://www.the-dma.org.uk/Topical/tiDets.asp?ItemID=159 [accessed 20 April 2005].

[UNIDIR] United Nations Institute for Disarmament Research (2003). Outer Space and Global Security. UNIDIR, Geneva.

Vernon, R. (1966). "International investment and international trade in the product cycle". Quarterly Journal of Economics 80 (2), 190–207.

Williamson, O. (1985). The Economic Institutions of Capitalism. Free Press, New York.

Wulf, H. (1983). "Developing countries". In: Ball, N., Leitenberg, M. (Eds.), The Structure of the Defence Industry: An International Survey. St. Martin's Press, New York, pp. 310–343.